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A TEXT-BOOK

ON

FIELD FORTIFICATION.

BY

G. J. FIEBEGER,

Professor of Civil and Military Engineering,
United States Military Academy.

FIRST EDITION.

FIRST THOUSAND.

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PREFACE.

In preparing this text-book for use in the course of instruction in field fortification at the United States Military Academy, the aim of the author has been to state briefly and clearly the principles of the art, and to illustrate them as far as possible by examples drawn from the experiences of field armies in recent wars; to show the relation which field fortification bears to the tactics of the battle-field and the strategy of campaigns; to modify the types of construction employed in the course to conform to the conditions imposed by modern firearms; and to omit the description of methods and constructions considered more or less obsolete.

Since the details of field fortification, like those of other engineering works, are susceptible of indefinite variation, the illustrations shown in the plates must be considered simply as types of construction, not to be slavishly followed, but modified to conform to the varying conditions of site and service.

To the chapters on field fortification proper have been added a few others, covering briefly the simple engineering operations of an army in the field. The subject of siege-works has been omitted from the present edition, as this subject is taught at the Academy in connection with military mining.

In his work the author has been aided by the suggestions of the officers on duty in his department, one of whom, Captain Chester Harding, Corps of Engineers, prepared many of the drawings.

G. J. F.

West Point, N. Y., Nov. 21, 1900.

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railway centres, are positions ordinarily protected by permanent fortifications. The works are usually constructed during time of peace, when the military engineer has at his command all the resources of the state. They are made sufficiently strong to resist all ordinary attacks of a field army. A position protected by permanent fortifications and properly garrisoned should yield only after a protracted siege. *Field* fortification deals with all defensive works of a temporary character which are constructed during a war, and which will lose their military value at its close. The works may be constructed by the field army with the tools which form part of its equipment, or by the reserve army utilizing all the resources of labor and material afforded by the surrounding country.

Field fortification may be divided into hasty or tactical intrenchment, deliberate or strategic intrenchment, and siege-works. *Hasty* or *tactical* intrenchment deals with all engineering devices resorted to by troops upon a battle-field to increase or prolong their fighting power. As its name implies, it is confined almost wholly to works which are executed in great haste in the immediate vicinity of the enemy. *Deliberate* or *strategic* intrenchment deals with the defensive works constructed by troops, not in line of battle, for the protection of depots, lines of communication and supply, lines of retreat, etc. As they are usually constructed at some distance from the enemy, they are more carefully designed than the hasty intrenchments of the battle-field and have greater defensive strength. *Siege-works* comprise all the engineering devices resorted to by the besieger and besieged in the attack and defense of a strong fortification.

In the application of the art of fortification, the three classes of field fortification frequently merge into each other. Thus an army occupying a good strategical position may hastily intrench itself for the simple purpose of fighting a defensive battle; successful in the battle but unable to take the offensive, it may gradually strengthen

its position until it has all the characteristics of a position deliberately fortified, and the assailant may find himself compelled to resort to a blockade or to a siege to secure its capture. The positions around Petersburg, Virginia, occupied by the Union and Confederate armies from June, 1864, to April, 1865, and those around Plevna occupied by the Turkish and Russian armies from July to December, 1877, were thus fortified.

However they may differ in construction, the *object* of each fortification is to modify the natural features of a position in such manner as—

(1) To increase the destructive effect of the fire of the troops covered by the fortification, and to facilitate their free movement upon the field of battle.

(2) To decrease the destructive effect of the fire, and to interfere with the free movement of the attacking troops.

To secure these objects the natural features of the position are modified so as to secure—

(1) An unobstructed field of fire in front of the line of defense.

(2) A shield or shelter which will protect the defender from the assailant's fire, or a mask which will conceal him from the assailant's view.

(3) An obstacle by which the advance of the assailant is retarded.

(4) Easy communications for tactical movements of the defender.

(5) Obstructed communications for the movements of the assailant.

Effect of the Development of Firearms.—From the middle of the sixteenth century until 1840, the infantry of the line was armed with a flint-lock, smooth-bore, muzzle-loading musket. It was uncertain in action, particularly in wet weather; its effective range did not exceed two hundred and fifty yards; and its rapidity of fire was limited to one and one-half shots per minute. Not being provided with adjustable sights, it was only fairly accurate

up to the point-blank range, which, with the bayonet fixed, was about one hundred yards. In our own service the percussion-lock replaced the flint-lock in 1842, and was in use until 1855. During the long era of the smooth-bore, the zone of aimed-fire in front of an infantry line was only one hundred to one hundred and sixty yards wide; it could be crossed by the attacking force in less than two minutes, during which time the defenders could fire but two volleys. The only kind of field fortification which was of any value to the defender was one composed of a strong obstacle, in the rear of which was some form of shelter for a line of troops. As such works were difficult to construct, earthen field fortifications were rarely employed upon battle-fields; the defenders sought to replace them by occupying villages, chateaux, and farms, whose house and inclosure walls, loopholed for defense, formed both the shelter and the obstacle. When a position was deliberately occupied, strong redouts were sometimes constructed, as at Borodino, by the Russians, in 1812, or abatis, as at Leuthen, by the Austrians, in 1757. All field fortifications were constructed by military engineers; they were employed not so much in battle-field intrenchment, as in the attack and defense of walled cities, and in the protection of encampments, bases, and lines of operation.

In 1855, in our service, the smooth-bore musket was replaced by a percussion-lock, muzzle-loading rifle; it was sighted to five hundred yards, and was as accurate at that nge as the smooth-bore had been at one hundred yards. this change the zone of aimed-fire was increased to four its previous width, and it became more difficult to . This was the weapon employed in our Civil War. ns of this war were, briefly, that troops could not ationary within the effective range of infantry cover, and that a well-intrenched line, occu- anks of seasoned infantry, could not be ult. These lessons were only gradually the close of the war the infantry of

both armies were supplied with intrenching tools carried in wagons, and they were freely used whenever an engagement was imminent. As the weapon was a muzzle-loader which could be loaded only in a standing position, and whose rapidity of fire did not exceed that of the musket, the shelters, where possible, were high enough to cover a soldier standing, and, where practicable, were protected by a strong obstacle.

In 1869, in our service, the muzzle-loader was replaced by a breech-loading rifle, which was sighted to 1300 yards, and with which twelve shots could be fired in one minute. This weapon increased both the width of the zone of aimed-fire, and the rapidity of fire over that zone. Two great wars were fought with similar rifles, the Franco-German and the Russo-Turkish. The effect of the new rifle was so great in these wars, particularly in the latter, that it caused not only a revolution in tactics, but led also to the introduction of instruction in the art of hasty intrenchment in the infantry of all great armies. In order that the soldier might never be separated from his intrenching tools, small portable ones were issued to all foot troops. Shelters were no longer required to cover soldiers standing, as the breech-loader could be loaded and fired from the kneeling and prone positions. Obstacles lost their importance, as the fire became so intense that it was almost impossible to approach an intrenchment over an unobstructed foreground.

About ten years after the Russo-Turkish War, in our own army in 1892, the simple breech-loader was replaced by a small-caliber, magazine-rifle sighted to 2000 or more yards. The new rifle has a high initial velocity and consequently a flat trajectory, which increases the chances of a hit at all ranges. The maximum rapidity of fire has increased to twenty shots per minute. The introduction of this weapon has again increased the width of the zone of aimed fire, and extended the zone in which troops must secure cover, as no troops can remain stationary,

without cover, within the limits of its accurate fire. With the small-caliber, magazine-rifle, smokeless powder is used. While black powder was the ordinary explosive, it was useless to attempt to conceal the trenches of the defense from the enemy's artillery and infantry, for they were certain to be exposed by the first volley. Since its introduction, however, it has been advantageous to mask them, so that they may offer a difficult target to the assailant's artillery and may not be easily recognized by reconnoitering patrols.

While the infantry arm was being developed from a smooth-bore to a magazine-rifle, the field-gun was also undergoing corresponding changes, becoming in succession a muzzle-loading and a breech-loading rifle; in the near future it may become a rapid-fire gun. The projectiles were in order of development, solid shot, shells, shrapnel, and torpedo, or high explosive shells. The effect of these changes has been to increase the range and effect of artillery fire to such an extent that even the reserves are compelled to construct artificial shelters, unless concealed or protected by the natural features of the site. The effect of the artillery of the attack has also been greatly increased by the curved and high-angle fire of howitzers and mortars, which have been added to the artillery of field armies. Covered shelters only will protect troops from a concentrated shrapnel or torpedo-shell fire of these guns.

CHAPTER II.

PROFILES OF HASTY AND DELIBERATE INTRENCHMENTS.

A *profile* is any section of a fortification made by a vertical plane, perpendicular to the principal lines of the work. The elevation or depression of any point of the work above or below the *plane of reference*, which is the plane of site, is represented by figures according to the methods of one-plane descriptive geometry.

Nomenclature of Profiles.—In Pl. II, Fig. 8, the broken line A,B,C, etc., R is the profile of a deliberate fortification in which AR is the *plane of site*, NOPQ *the trench*, HIJKLM the *parapet*, and DEFG the *ditch*. The nomenclature of the different lines and angles of the profile is as follows:

QR, the site in rear of the shelter, is the *parade*.

LN is the *banquette slope;* in this profile it is replaced by steps.

KL is the *banquette tread* upon which the troops stand to fire over the parapet.

JK is the *interior slope* of the parapet.

IJ is the *superior slope* of the parapet.

HI is the *exterior slope* of the parapet.

GH is the *berm*.

FG is the *scarp*.

DE is the *counterscarp*.

BCD is the *glacis*.

CD is the *interior slope* of the glacis.

BC is the *superior slope* of the glacis, or the *glacis slope*.

AB, the site in front of the work, is the *foreground*.

The bottom line of a slope is called its *foot*, the top line its *crest;* thus K is the foot and J the crest of the interior slope. The *height of the parapet* is the elevation of the interior crest above the plane of site; its *relief* is the elevation of the interior crest above the bottom of the ditch; its *thickness* is the perpendicular distance between vertical planes containing the interior and exterior crests, and its *command*, with respect to any point, is the vertical distance of its interior crest above that point. The principal line of any field fortification is the most elevated line of the parapet, viz., the crest of the interior slope. It is usually called the *interior crest*, or simply *the crest;* in hasty intrenchments it is also known as the *line of fire*, or the *line of combat.*

Classes of Profiles.—The time and tools at the disposal of the troops, as well as the fire to which they will probably be exposed, have given rise in field fortification to three classes of profiles, viz., one to resist rifle fire only, one to resist field-guns, and one to resist light siege-guns. The first and second are usually employed in hasty, and the third in deliberate intrenchment.

Profiles to Resist Rifle-fire.—At ordinary battle ranges a thickness of from 2½ to 3 feet of ordinary earth will stop a rifle bullet. The simplest method of securing this protection is by constructing a *skirmisher's* trench [Pl. I, Fig. 1], which gives cover to a man lying down in the trench. To enable him to fire over the parapet the height of the latter should be about one foot. A trench covering a single man, one pace or 2½ feet front, can be constructed in soft ground with the simplest, or even improvised intrenching tools, in *twenty minutes.* For troops in the main line of resistance the simplest trench is the *kneeling* trench [Pl. I, Fig. 2]. The width of this trench at the bottom is at least 2½ feet, preferably 3 feet, and the crest of the parapet [illegible] feet above the bottom of the trench, this being the [illegible] at which a man, kneeling, holds his rifle in firing. [illegible]rench can be constructed in soft ground with the

small or large intrenching tools in *forty minutes*. As troops in a kneeling trench are in a constrained position, it is converted, as soon as possible, into a *standing* trench, as shown in Pl. I, Fig. 3. The width at the bottom of the trench is about the same as in the kneeling trench; the crest of the parapet is $4\frac{1}{3}$ to $4\frac{1}{2}$ feet above the bottom of the trench. The standing trench can be executed in soft ground with large intrenching tools in *two hours;* or a kneeling trench can be converted into a standing trench in about *one hour and twenty minutes*. The standing trench does not give complete cover to men moving about the trench, and it is finally completed by excavating, in the rear of the trench, a passageway which is 6 feet below the interior crest [Pl. I, Fig. 4]. This is the *complete* trench which can be constructed in soft ground with large intrenching tools in *four hours*, if all the material is placed in the parapet. The height of the parapet of the complete trench is the same as that of the standing trench; this makes the parapet thicker than necessary to resist rifle bullets, but renders the conversion of a standing into a complete trench a simple process. To increase the rapidity of construction some of the earth excavated from the trench may be wasted over the parade in rear.

Remarks on Shelter-trenches.—The shelter-trench, in which the area of the profile of the parapet is equal to that of the trench, can be constructed in the shortest time and with the least amount of labor; it may, however, not fulfill the tactical requirements of each position, and must frequently be modified. The command of the parapet of a trench depends upon the character of the foreground and of the soil. To obtain a good view of the foreground, or because of rocky or marshy soil, it may be necessary to omit the trench and construct the shelter wholly in embankment; if the foreground is clear, the soil easily excavated, and of a character to maintain a steep slope, the parapet may be omitted, and the shelter constructed wholly in excavation [Pl. I, Fig. 5]. The excavated earth

is strewn over the ground either in front or in the rear of the trench. The height of the parapet and the depth of the trench may be varied between the above limits, to suit the site; the types given are those which would ordinarily be employed in open ground when it is desired to save time and labor. An objection to all trenches is the difficulty of draining them. If a position is to be occupied for some time, it will usually be best to make all shelters in level clayey ground or in other sites not easily drained, in embankment, by excavating the earth from the ditch.

In the construction of the parapet all sharp angles which make it more visible should be avoided. An offset in the interior slope, as shown in Pl. I, Fig. 3, forms a rest for the elbow and a shelf for cartridges. When rails or tree trunks can be procured they may be used to replace earth filling in the parapet. Parapets of freshly excavated earth indicate to the assailant the position of the line of defense; they should, therefore, be covered with sod, brush, or weeds to conceal them. Deep trenches must be provided with steps at intervals for communication with the parade, and all trenches which are to be occupied for any length of time should be provided with drainage ditches. Tactically the skirmisher's and kneeling trenches may be classified as *offensive* trenches, as they do not interfere with the forward movement of the troops; the former is constructed by the assailant, and the latter by the defender to cover troops who are to make a counter attack. The standing and complete trenches on the contrary are *defensive* trenches, as they interfere with the forward movement of the troops and are intended for passive defense.

Covering Trenches.—Whenever the supports and reserves cannot be protected from the assailant's fire by natural shelters, they must construct covering trenches. The ordinary kneeling trench will cover troops sitting in the ...h with their backs to the parapet. The trench should, ... permits, be widened to 42 or 45 inches by throwing ...d to the rear. Pl. I, Fig. 7, is a profile of a

covering trench for reserves constructed by the Russians in their lines of investment about Plevna. It can be constructed by men working on both sides of each embankment in about two hours. This trench may be improved by constructing steps in one or both slopes upon which the men can sit. If exposed to accurate artillery or infantry fire, the covering trenches for supports should be connected with those of the firing line by communicating trenches.

In the profiles shown on Plate I, the side slope of embankments is assumed as $\frac{1}{1}$, and that of excavations as $\frac{3}{1}$; in practice each would be made as steep as the nature of the ground would permit. The thickness of the parapet is based on ordinary earth, and may be decreased one-fifth for sand and must be increased one-fifth for clayey soil.

Profiles to Resist Field-guns.—In every position taken up by a body of troops to fight a defensive battle, there will be key points, the possession of which will determine the fate of the battle. These points will be vigorously bombarded by the assailant's artillery, to prepare for the infantry assault. The defenders occupying them must, therefore, be sheltered from shrapnel and shell fire during this bombardment. The angle of fall of field artillery shrapnel or shell at 3400 yards is eleven degrees; the angle of dispersion of the former is fourteen degrees; this makes the angle of fall of the most dangerous fragments about eighteen degrees, or $\frac{1}{3}$. The penetration of shrapnel and shell fragments is resisted by 3 feet of earth, and the penetration of single shells by from 4 to 6 feet of earth. As shrapnel is the ordinary projectile used by the field artillery upon the battle-field, the parapet of the trench should be at least 3 feet thick, and its interior crest should be at such a height above the bottom of the trench that a shrapnel fragment grazing it, at an angle or fall of $\frac{1}{3}$, will pass over the heads of the men kneeling or sitting in the trench. Pl. IA, Fig. 7*a*, is a profile to resist field-gun shrapnel, formed by modifying the trench and parapet of a complete shelter trench; men sitting upon the lower steps

and in the bottom of the trench are secure against shrapnel fire. This profile can be executed in favorable soil with large intrenching tools in *four* hours.

If a field fortification is liable to be exposed to a prolonged attack of field-guns, the parapet should be proof against field-gun shells. This requires a parapet of ordinary earth 9 feet thick, and may be constructed as shown in Pl. I, Fig. 6, by increasing the thickness of the shrapnel parapet with earth excavated from a ditch in its front. This profile can be executed in favorable soil, with large intrenching tools by working parties in ditch and trench, in *four* hours.

Pl. IA, Figs. 7*b* and 7*c*, indicate the manner of converting a skirmisher's trench into a profile for resisting a prolonged attack of field-guns, by passing through the intermediate forms of trenches. The corresponding areas in embankment and excavation are similarly shaded.

Profiles to Resist Light Siege-guns.—The angle of fall of the projectiles of siege-guns is approximately the same as that of field-guns; the *bottom* of the trench is therefore kept 6 feet below a plane passed through the interior crest with a slope of $\frac{1}{8}$ [Plate II, Fig. 8]. In order to secure easy communication about the works, its width is increased to at least 6 feet. The penetration of a single shot from a siege-gun is from 10 to 13½ feet. To comply with the general rule that the thickness of the parapet should be one and one-half times the penetration of the projectile which it is intended to resist, the thickness of the parapet should be from 15 to 20 feet. In the defenses of Washington constructed during the Civil War, the maximum thickness was 12 feet; at Plevna in 1877–78 the maximum thickness of the Turkish works was 16½ feet. The parapet should be high enough to give a good view of the foreground and to screen the defenders standing on the parade, from the view of the assailant when standing upon the foreground [illegible] accurate rifle range. Upon level ground the height [illegible] parapet is usually between 6 and 8 feet.

The *interior slope* is revetted and made as steep as possible to afford protection from shrapnel, to the men at the parapet and in the trenches; for the same reason the banquette slope is replaced by steps. If the interior slope is revetted, the *banquette* is placed about 4½ feet below the interior crest and is made 2 to 3 feet wide. The *banquette slope* is usually replaced by steep steps so as to bring the trench as near as possible to the interior crest and thus give better protection to the men against shrapnel fire. The *superior slope* of the parapet is arranged to sweep the foreground, and usually has a slope of $\frac{1}{8}$; in order not to weaken the parapet too much at the interior crest, the maximum inclination of the superior slope is fixed at $\frac{1}{4}$. The *exterior slope* is given the natural slope of the material of the parapet, or a less inclination. The *berm* is left 1 to 2 feet wide, or is wholly removed. The berm forms a convenient shelf upon which to throw earth in forming the parapet and to hold branches in masking the work; on the other hand it assists the assailant in mounting the parapet. Whenever, therefore, the ditch is the principal obstacle in front of the work, the berm should be removed; otherwise it may be retained.

The object of the *ditch* is primarily to furnish earth for the parapet; theoretically, to secure rapidity of construction, the amount of excavation from the trench and ditch should be in the inverse ratio of the distance of the centre of gravity of each from the centre of gravity of the section of the parapet; practically the latter is so nearly midway between the trench and ditch that the areas of the ditch and trench should be about equal to each other. When the ditch serves also as an obstacle to assault, it should be at least 6 feet deep and 12 feet wide, and the scarp and counterscarp should be made as steep as possible. To secure these dimensions the area of the profile of the ditch must be much greater than that of the trench, as in Pl. II. Fig. 8. If the inclination of the superior slope is such that fire from the interior crest cannot reach the assailant in the foreground at the crest of the counterscarp, the foreground

is raised by the construction of a *glacis*. A glacis may also be constructed when all the earth excavated from the ditch is not required in the construction of the parapet. Pl. II, Fig. 8, is a profile of a deliberate intrenchment to resist siege-guns, in which the thickness of the parapet is 15 feet and its height 7½ feet. The glacis in the profile is unnecessary, but is added simply for purposes of explanation. This profile can be constructed in about five days.

To secure the maximum effect of the infantry rifle, a deliberate fortification should be so constructed as to give at least two tiers of infantry fire. This may be done as indicated in Pl. II, Figs. 9 and 10. The former is a profile employed by the Turks in the defenses of Plevna; it has a banquette for infantry constructed in the counterscarp. The latter is a profile employed by the Russians in their investing works around Plevna; it has a second trench between the main parapet and the ditch. In constructing these advanced infantry positions, care must be taken that the superior slope of the main parapet prolonged, passes at least 6½ feet above the banquette tread of the advanced position, so that the advanced line of infantry is not exposed to the fire of the main line in their rear.

Pl. II, Fig. 11, is the triangular profile, in which the ditch is shallow and wide, and contains a strong obstacle, usually a high wire entanglement. In this profile the parapet is inconspicuous, and cannot be destroyed by siege-guns, howitzers, or mortars. Its principal defect is that in its construction the excavated earth must be moved a considerable distance horizontally. If horse-power is available this defect is immaterial.

Masks.—In intrenching any position, if time and means do not permit the construction of profiles of full dimensions, it should be remembered that any mask which conals the defender decreases the effect of the fire of the ailant, and consequently increases the morale of the de- er; and that many projectiles which hit the parapet penetrate as deeply as indicated in tables of pene-

CHAPTER III.

HEAD-COVERS, ARTIFICIAL SHELTERS OF WOOD, IRON, STONE, ETC., AND ACCIDENTAL SHELTERS.

Head-covers.—Additional cover may be given troops defending an open field fortification, by the construction of shields to protect the heads of the men engaged in observing the enemy or in firing over the parapet. These shields are head-logs, bonnets, and loopholes. A *head-log* [Pl. III, Fig. 12] is a roughly squared or round log which is placed above the parapet, parallel to the interior crest, on skids or on earthen mounds, so as to leave a space between the parapet and the under side of the log. The log should be of hard wood and, for thorough protection, at least 20 inches square. The amount of cover may be increased by cutting notches in the under side of the log, and placing it in contact with the superior slope of the parapet. A similar construction of iron plates, or of wood covered with iron, is sometimes used in place of the head-log. In our Civil War it was customary to let the skids project well over the interior crest, so that if the head-log was struck by a cannon-shot, it was thrown to the rear without injuring the men defending the parapet. *Bonnets* are bullet-proof mounds erected on the superior slope of the parapet to protect the defenders from oblique fire. They are of doubtful utility, as they define the positions of the men defending the parapet. *Loopholes* are apertures formed of sand-bags, gabions, boards, etc. A sand-bag loophole is made by laying upon the parapet, perpendicular to the interior crest, two sand-bags, with an opening of

3 inches between them; these are covered with two others laid parallel to the crest. The space between the loopholes is made bullet-proof, by a mound of sand-bags or of earth. Gabion loopholes are made by setting up two gabions filled with earth, leaving a space of 3 inches between them; they are covered with sand-bags or fascines. Board loopholes were used during the Civil War; Pl. III, Fig. 13, shows one made of four trapezoidal boards and employed in the Union works about Richmond and Petersburg. The splay was such as to make the exterior opening 2½ inches square, and the interior opening 8 inches high and 14 inches wide. The interval between loopholes is one pace or one yard, the length of interior crest defended by each man. Head-covers are constructed only when the intrenched lines of attack and defense are within accurate range of each other.

Shelters of Wood.—In a heavily wooded country, as the theatre of our Civil War, wood is extensively used instead of earth in the formation of hasty intrenchments, as the roots frequently prevent excavation. The modern rifle can, at short ranges, penetrate 37 inches of soft and 20 inches of oak wood. For thorough protection shelters of soft wood are made 40 inches and of oak 24 inches thick. The simplest shelter is formed by a pile of rails or tree-trunks about a foot high, over which is thrown a little earth; it corresponds to the skirmisher's trench, and was frequently used in the Civil War. A parapet of ordinary height for troops standing, is called a *breastwork*. It may be constructed by sinking into the ground two parallel rows of posts and filling the space between them with rails or tree-trunks; one form is shown in Pl. III, Fig. 14. A covering of earth lessens the danger of their destruction by fire. A breastwork which will resist rifle fire will also resist fragments of shell and shrapnel; to resist direct penetration of shells of field artillery the thickness of the breast-

must be increased, with timber or earth, to 8 or 10

stockade is a combined shelter and obstacle made

by planting, upright in the ground, one or more rows of posts. The posts should be at least 10 feet long, and planted in close contact at least 3 feet in the ground. Cleats or iron dogs are used to fasten them together both above and below ground. The tops are sharpened or provided with spikes to prevent escalade. If the stockade is not bullet-proof, it may be made so by constructing in its rear a thin parapet which is revetted, or retained by boards or planks, supported by small posts. For defensive purposes the stockade is loopholed as shown in Pl. III, Figs. 15, 16, and 17. To prevent the assailant using the loopholes in a stockade or other vertical wall, they should never be placed at the height above the foreground convenient for use by men lying, standing, or kneeling. A ditch is frequently dug in front of the stockade or wall to prevent the assailant from using the loopholes.

Shields of Iron and Steel.—A thickness of $\frac{1}{2}$ inch of wrought iron or $\frac{5}{8}$ inch of steel is proof against small-arms fire. Plates are used to strengthen wooden doors, etc., and breastworks of steel rails, to protect railway bridges and stations.

Shelters of Stone and Gravel.—A thickness of 8 inches of broken stone or gravel between one-inch pine boards is proof against rifle fire. This is a convenient form of parapet to obstruct a macadamized or gravel roadway.

Well-packed snow, grain-sheaves, cotton-bales, etc., may also be used in the construction of shelters against infantry fire; the thickness required will be found in Appendix B.

Accidental Shelters.—Accidental shelters are those features of a battle-field which can be utilized, with or without modification, to replace ordinary hasty intrenchments. These are walls, hedges, fences, embankments, and excavations.

Walls.—A brick wall one header thick will resist a single rifle-shot, and a wall 20 inches thick will resist an infantry attack; a stone wall has a greater power of resist-

ance. Therefore a wall about 1, 3, or 4½ feet high can, without modification, be used instead of the skirmisher's kneeling or standing trench ; other heights may be utilized by the construction of banquettes at the proper distance below the top of the wall, as in Pl. III, Fig. 18. For the purpose of securing head-cover, a wall may be crenelated or loopholed. A *crenelated* wall is one in which vertical openings have been cut from the top of the wall to the desired elevation of the line of fire ; these openings are about 3 inches wide. If the wall is thin, a *loophole* is usually constructed by removing a header from the face or back of the wall and breaking out the remainder ; the loophole has its splay in only one direction and preferably to the rear. In thick walls the splay is from the interior of the wall in both directions. The size of the loopholes must depend upon the desired field of fire ; the smallest dimension is usually about 3 inches. If a wall is 6 feet or more in height [Pl. III, Figs. 19 and 20], it not only forms a good obstacle and screen, but allows of the formation of two tiers of fire. If the two tiers are secured by means of loopholes, those of the upper tier should be over the intervals of those in the lower so as not to unduly weaken the wall. Loopholes and crenelations indicate to the enemy that the wall is prepared for defense, and may be sometimes constructed simply to deceive him. A wall of brick 40 inches thick will resist single artillery projectiles, but will soon be destroyed by a continuous bombardment ; splinters being thrown as far as 50 or 60 yards to the rear. The wall may be strengthened by constructing a parapet of earth in contact with its face or back. Brick walls which resist rifle fire will also resist the penetration of fragments of shell and shrapnel.

Hedges.—Hedges make excellent lines of defense ; if high enough, they conceal the movements of troops in their rear, and with a few barbed wires can be converted [illegible] strong obstacles. In utilizing a hedge, a shelter-trench [illegible]tructed close behind it with its parapet against the [illegible]t above the parapet the hedge is thinned out

so as not to interfere with the view and fire of the defenders [Pl. III, Fig. 21.]. In this position the earthen parapet cannot be seen by the enemy, and he will be uncertain as to the nature of the defense. If it be desirable to make him think the hedge a strong position, when it is but weakly occupied, the parapet may be constructed along the front of the hedge so that it is visible from the foreground.

Fences.—Close board fences, [Pl. III, Fig. 22], may be used as screens by constructing a shelter-trench close in their rear, and leaving a horizontal opening about 3 inches wide at the level of the interior crest. The materials will, however, ordinarily be of more value to the troops in the construction of covered shelters. Rail fences were extensively used in our Civil War, the rails being simply thrown into piles and covered with earth. An open fence of iron pickets or wire is valuable as an obstacle to retain the enemy at some distance from the line of defense, but may also be defended by constructing a parapet in contact with it.

Embankments.—An embankment, such as a causeway, may be converted into a defensive line [Pl. III, Fig. 23] by excavating a trench in it, or the entire embankment may be used as a parapet. The former method is the better, as the foreground can be more thoroughly swept. A communicating trench should render the shelter-trench accessible to the supports who are placed behind the embankment.

Excavations.—If the foreground is clear, deep-sunken roads or similar excavations form the best accidental shelters, as the troops are completely protected from fire and are concealed from view. To prepare an excavation for defense it is only necessary to construct a banquette in the face of the slope on the side towards the enemy [Pl. III, Fig. 24]. Sometimes it is better to employ a sunken road as an obstacle and construct a shelter-trench in its rear. Excavations are particularly valuable as defensive positions, because they afford no visible target to the assailant's artillery, and give to the assailant's infantry no indication of their extent or the numbers of the defending force.

CHAPTER IV.

PREPARATION OF THE FOREGROUND AND OBSTACLES.

To secure the best results from the accuracy and rapidity of fire of the magazine-rifle, the ground in front of the line of defense should be free from all obstacles which would mask or shelter the assailant. The distances to objects in the fire-zone should be known, and the advance of the assailant checked while he is under the close fire of the defender. The operations by which these conditions are secured are known as the preparation of the foreground and the construction of obstacles.

Preparation of the Foreground.—Standing crops are mown down and used in covering the parapets of the shelter-trenches, or are trodden down by the cavalry or infantry. Piles of stone, wood, straw, and refuse, unless utilized as range targets, are scattered. Brush, orchards, groves, vineyards, etc., are cut down and used in the construction of obstacles, or in filling up dead spaces in the foreground. (A *dead space* is any space which cannot be reached by fire from the parapet in its rear, as an excavation.) Inclosure walls, hedges, embankments, and close board fences so nearly parallel to the line of defense that they cannot be satisfactorily swept by its fire are thrown down or removed. Similar obstructions which are perpendicular to the line of defense or are well swept by its fire, as well as all open obstructions, such as iron and wire fences, are retained. [illegible] are burned, removed, or put in a state of defense. [illegible] to all conspicuous objects in the foreground, [illegible] stumps, and stones, which are useful in

determining the range of the assailant are carefully measured. Isolated trees and buildings along the line of defense which might be used by the assailant's artillery in determining the range are removed. The breadth of the fire-swept zone thus prepared depends upon the troops, time, and tools available for the work; if possible it should extend outwards from the line of defense 600 yards in battle-field intrenchments, and still further in deliberate intrenchments.

Obstacles.—Obstacles are employed in connection with field fortifications to protect the works from surprise, to break up the assailant's formations, and to hold his troops, for a time, under the accurate fire of the defender. To be most effective, their location should be concealed from the assailant, they should neither give him cover nor conceal his movements, and they should be difficult to destroy by manual labor, explosives, or artillery. Obstacles may be placed either in front of or along the line of defense. If in front of the line, they are most effective if they are under the close infantry fire of the defense, under close observation at night, near enough to the line of defense to compel the assailant to cease his artillery fire before his infantry reaches them, and far enough from that line to save them from destruction during the artillery bombardment which precedes the infantry attack. The zone from 50 to 100 yards in front of the work best fulfils these conditions. Obstacles along the line are either in the ditches of the fortifications, or in the intervals between the works of an intrenched line. For passive defense the obstacles in front of the defensive line should be continuous; for active defense they are omitted, or employed only in the defense of salients and key-points.

Obstacles are also used in connection with field operations, to close gaps in a line of defense, when the line is too long to be properly defended throughout by the number of available troops, and to obstruct the advance of an enemy along any natural lines of operations. The latter is

most easily done where these lines follow defiles in forests or mountains.

Slashings and Abatis.—A slashing is formed by felling a belt of trees so that their branches will interlace; the trunks are not wholly detached from the stumps. A slashing in front of a line conceals the movements of the enemy; it should therefore be made impenetrable, and its sides should be well flanked. A slashing 40 to 60 yards wide fulfils the first condition; if narrower, wires should be drawn through it and fastened to the branches. Slashings are particularly suitable for obstructing roads, ravines or other depressions, and fords, as well as for closing gaps in a line of defense. An *abatis* is formed by placing one or more rows of trees with their trunks perpendicular to the line of defense, and with their branches interlaced and extending towards the enemy. The foliage and small twigs are removed, the large branches pointed, and the trunks firmly pegged to the ground. The whole may be strengthened by connecting the trees with wires so as to prevent the removal of any single tree. If in front of the defensive line, the abatis should be placed in a trench or natural depression so as to conceal it from the enemy. If the abatis is constructed some distance from the woods where the trees are cut, it is advisable to use only saplings and large branches, and to make it several rows deep [Pl. IV, Fig. 25]. In hasty intrenchments care must be taken that the abatis does not conceal the foreground, or interfere with the fire of the defense. Abatis are also used to close gaps made in walls, palisades, etc. A *zareba* is an inclosure surrounded by an abatis made of thorny bushes; it is employed in countries where such bushes are common, as in Egypt.

Entanglements.—An entanglement is formed of stakes, stumps, or bushes, connected by wires, ropes, or vines, arranged to trip or to stop an assailant. A *high wire entanglement* is usually made by driving stakes in rows or in ·unx order about 6 feet apart so as to make a belt 18

to 30 feet wide. The stakes nearest the enemy are 6 feet long and are driven into the earth about 3 feet; the others may be 4½ feet long and are driven into the earth about 1½ feet. In the construction of an entanglement the stakes should not all be of exactly the same height, and they should be spaced somewhat irregularly, as it is more difficult to cross an irregular entanglement than a regular one, by covering it with boards or fascines. The stakes in the front and rear lines are connected by horizontal barbed wires, 1, 2, and 3 feet above the ground, forming a barbed-wire fence. These and the other stakes of the entanglement are also connected by different systems of diagonal wiring [AB, AC, AD, AE, Pl. IV, Fig. 26]. The wires are loosely drawn and wrapped around the stakes, and may be made fast to them by staples. Where wires cross they may be fastened together with finer wires. High wire entanglements are used in deliberate intrenchment. *Low wire entanglements* are formed of short stakes which project about 12 or 18 inches above the ground, and of wires, preferably barbed, which connect the tops of the stakes. The stakes should be 4 to 6 feet apart and the entanglement 30 feet wide. The low entanglement is most effective when it is concealed by low brush or high grass. Low wire entanglements were first used by General Gillmore, Corps of Engineers, in the siege of Fort Wagner, S. C., in 1863. They were made by driving three rows of stakes and connecting them and an inclined palisade by wires about 12 or 18 inches above the ground. The stakes were 3½ feet long, and were driven 2 feet into the ground, in quincunx order, with intervals of 7 feet.

Slashings, abatis, and low entanglements are the obstacles usually employed in hasty intrenchment; there are others occasionally used in hasty intrenchment, but more generally in the construction of deliberate field fortifications.

Palisades.—A palisade is a vertical or inclined fence, made of round or split posts fastened together by two or

more cleats, and planted in the ground about 3 feet. Palisades were extensively used during the Civil War. From their experience at the siege of Fort Wagner, the engineers under General Gillmore recommended that a palisade should be made in panels of four or five poles, according to the size of the stuff used, care being taken to leave no opening through which a man could force his body. They found that round poles made better palisading than split ones. If the former were used, they were not less than 4 inches nor more than 6 inches in diameter at the large end; if the latter, they were not less than 5 inches nor more than 8 inches in diameter at the large end, and were split only once. Two-inch planks made better cleats than split stuff. Inclined palisades made of split stuff were found to be stronger when the bark side was placed up. In Pl. IV, Figs. 27 and 28 show the forms of palisade used in the siege of Fort Wagner. A palisade is used in a position not exposed to artillery fire.

Fraises.—A fraise is an obstruction which prevents easy entrance into or exit from the ditch or other excavation. It is usually constructed in the form of a palisade or wire fence, and is laid horizontally or slightly inclined under the parapet or the glacis, whence it projects over the ditch [Pl. IV, Fig. 29]. The name is also applied to inclined palisades.

Crowfeet or Caltrops, Small Pickets, etc.—Crowfeet are made of four spikes welded together at their heads in such a manner that if thrown on the ground one point will always be up. Harrows and boards fitted with projecting spikes will serve the same purpose. Small pickets are short, sharp-pointed stakes driven at intervals of 1 foot. They are invisible to the enemy, and prevent the attacking troops from securing cover by lying down in the zone of obstructions. Crowfeet have been used to obstruct fords, and were employed in some of the campaigns of Egypt, to [illegible]re with the rushes of the Arabian hordes.

[illegible]ry Pits.—A military pit is a conical or pyram-

idal excavation about 2 feet deep, in the bottom of which is planted a short, sharp stake. The pits are arranged in quincunx order, in three or more rows, in contact with each other, or separated by slight intervals; in the latter case the space between the pits is planted with short pickets [Pl. IV, Fig. 30]. A low entanglement may be constructed over the pits.

Chevaux-de-frise.—A cheval-de-frise is composed of a body of timber about 8 inches square and 6 feet long, and twelve lances of iron or wood 6 feet or 8 feet long, strong enough to resist being broken by hand. The lances are fastened at right angles to the body, so as to project equally on either side; the adjacent lances are perpendicular to each other [Pl. IV, Fig. 31]. Chevaux-de-frise are fastened together with chains and used in barricading streets and roads against cavalry. They are also used to close passages left through a parapet or other shelter.

Ditches.—The ditch is made an obstacle by giving it a depth of 6 feet and a width of 12 feet. It may be made more formidable by revetting the scarp and counterscarp with timber, or by constructing in it an abatis, entanglement, palisade, or other obstacle [Pl. IV, Fig. 32].

Inundations.—If a stream runs parallel to the line of defense, or intersects that line coming from its front, the foreground may be inundated by constructing dams which must be under the close fire of the defense. An inundation is a difficult obstacle to cross, as it prevents the assailant from securing any cover by the construction of shelter-trenches. Pits and ditches, dug before the ground is covered by the water, increase the difficulty of crossing.

Land Mines.—These are small charges of explosive placed in ordinary shells and arranged to explode under the weight of a man or by electricity. They are planted in front of the work in the ditch, or in some depression where they will not be exposed to artillary fire. Land mines were used in the defense of Fort Wagner, Charleston harbor, and consisted of 24-pound and 9-inch spherical

shells, and 10-gallon kegs filled with powder. They were arranged with percussion fuses so as to explode under the tread of the attacking troops. Such mines are dangerous to friend and foe alike. Mines would now be arranged to be exploded, either automatically or at the will of the operator, by the closing of an electric circuit through the detonating fuse.

Fougasses.—A *stone* fougasse is a mine so arranged that upon explosion a sector of the foreground is swept by a hail of stones. It is constructed by excavating a funnel-shaped hole of sufficient size to contain the desired charge of stones [Pl. IV, Figs. 33 and 34]. At the bottom is placed a box or can containing powder, and in its front, resting on a thick plank, is the charge of broken or cobble stone. Sixteen pounds of powder are used for each cubic yard of stone. The powder is fired by an ordinary safety fuse or by an electric current. If placed in front of the ditch of a redout, the fougasse should be several yards from the ditch, and the excavated earth should be piled on the side towards the work so that no missiles may be thrown to the rear. The fougasse should be concealed from the enemy by a screen of brush or other light material. An experimental fougasse constructed at the Engineer School at Willets Point, with 25 pounds of deteriorated mortar powder, threw its charge of broken stones over an area, whose extreme depth was 200 yards. A fougasse checked a Turkish attack on the Russian defenses in Shipka Pass during the Russo-Turkish war of 1877–78. A *shell* fougasse is a box containing shells buried in the earth. The box is divided by a horizontal perforated partition into two parts; the upper contains shells and the lower a charge of powder sufficiently large to throw the shells to the surface. It is fired by an ordinary safety fuse or by a current of electricity.

Barricades.—A barricade is a hastily constructed obsta-
e to bar the passage of a road, street, or other defile.
arricades are used principally in the defense of cities

and villages, and are made of paving material, household furniture, boxes, casks, and bags filled with earth, etc. A barricade may be commanded by a parapet in rear, or it may be swept through loopholes constructed in the adjacent houses. A passage through a barricade is temporarily closed by a cheval-de-frise or by a wagon with chained wheels.

To Remove Obstacles.—A passage through a slashing is made by exploding a line of guncotton or dynamite charges attached to the obstructing branches, or by removing these branches with axes. An abatis is removed by cutting the wires, removing the pegs, and hauling out the individual trees or branches, with ropes. A wire entanglement is removed by cutting or pulling up its stakes, and cutting its wires. The wires are cut with wire cutters or with hatchets using a piece of iron as an anvil. A passage is made over an entanglement by covering it with fascines, boards, hurdles, etc. Palisades or stockades are either cut down or destroyed by explosives. Crowfeet, harrows and small pickets are either removed or covered with fascines, bundles of straw, etc. Military pits are filled with earth or bags of straw, covered with boards, etc. Chevaux-de-frise are either moved or destroyed with axes. A ditch is filled with bags of straw, fascines, etc., or is crossed by means of ladders. Inundations are drained by destroying the dams; they are then crossed by roads made of fascines, hurdles, brush, etc. Mines must be avoided, as they cannot be removed or passed over without considerable loss. Walls are surmounted by ladders or blown down by explosives.

CHAPTER V.

CLASSIFICATION OF FIRE, ARTILLERY-SHELTERS, AND PLATFORMS.

Artillery and Infantry Fire.—[Pl. V, Fig. 42.] The artillery fire to which an intrenched line of troops may be subjected is, in the horizontal plane, *front* or *frontal* when it is received directly from the front; *oblique* when received obliquely from front or rear; *enfilading* when received from the prolongation of the line; *reverse* when received from a battery in the rear of the line.

The combined moral and destructive effect of the artillery fires to which an intrenched line may be subjected, and the difficulty of protecting the troops against them, increase in the order above named. In laying out a line, therefore, it is essential to study the foreground within artillery range, so that no part of the line will be exposed unnecessarily to the reverse or enfilade fires of the assailant's batteries.

The artillery fire of a line is *front* or *frontal* when delivered normally, and *oblique* when delivered obliquely to the general line. *Flanking* fire is any fire which is parallel to and in front of the line. *Cross* fire is that produced by concentrating fires from different directions upon a single target.

The artillery fires of the defense over the foreground of an intrenched line increase in their moral and destructive effect on the troops making the assault, in the order of ıt, oblique, cross, and flanking. The batteries of the ıould, therefore, be so located that they can bring cross fires on the foreground in front of the key-

points of the line and all points which are naturally weak, and front or oblique fires over the foreground of the less important and naturally strong parts of the line.

In a vertical plane *direct fire* is that obtained from guns with service charges at angles of elevation not exceeding 15°. *Indirect*, or *curved*, *fire* is that obtained from guns with reduced charges, or from howitzers and mortars at angles of elevation not exceeding 15°. *High-angle*, or *vertical*, *fire* is that obtained from guns, howitzers, and mortars at angles of elevation exceeding 15°. *Grazing fire* is that which passes close to the surface over which it is aimed. *Plunging fire* is that obtained from a gun placed upon a much higher elevation than its target.

Troops may be protected from direct and curved fires by parapets and traverses, but overhead shelters are necessary for their protection against high-angle and plunging fires.

Infantry fire has the same classifications in the horizontal plane as artillery. In the vertical plane it is divided into three zones, viz., the *short* or *decisive zone*, up to 600 yards, in which the trajectory is flat and aimed fire is directed upon individuals and squads ; the *medium zone*, from 600 to 1100 yards, in which fire is directed in volleys at different elevations and only at high or wide targets ; *the long zone*, from 1100 yards onwards, in which the fire is delivered in volleys at two or more elevations, at high, wide, and especially deep targets, as wide and deep columns of troops.

In protecting troops against infantry fire, all aimed fire may be considered either direct or curved ; unaimed long-range fire approximates to the high-angle fire. The effect of the infantry fire of an intrenched line decreases as the range increases and as the ground becomes more irregular. The most effective fire is, therefore, front, grazing fire, and the position should be chosen and the line so laid out, if possible, as to secure a front, grazing fire over the foreground to a distance of 600 yards.

Artillery-shelters.—Shelters for field-artillery upon the battle-field are constructed when the guns are to occupy for some time a position selected in advance. The shelters are called *gun-pits*, and the parapets *epaulements*.

Gun-pits.—In protecting a battery in position, it is essential to protect first the cannoneers, and then the gun. The German gun-pit, which fulfils these requirements is begun by excavating two covering trenches for the cannoneers as shown in Pl. V, Figs. 35 and 36. Each trench is made by first excavating an area 5 feet square to a depth of $1\frac{3}{4}$ feet; and then excavating the middle third to the full depth of $3\frac{1}{2}$ feet. The front line of the trenches is slightly in rear of the axle of the gun; the distance between the inner edges of the trenches is 13 feet. The earth excavated forms a parapet $1\frac{3}{8}$ feet high. The task in each trench is about 2 cubic yards. The pit is completed as shown in Pl. V, Figs. 37 and 38, by excavating to a depth of $1\frac{3}{4}$ feet, the rectangle between the covering trenches, its extension $4\frac{1}{2}$ feet to the rear, and its extension $3\frac{1}{2}$ feet to the front in the form of a trapezoid whose parallel faces are 10 and 13 feet respectively. The excavated earth forms an epaulement $1\frac{3}{8}$ feet high extending across the front of the pit and along the sides of the covering trenches; the pit is connected with the ground in the rear by a ramp 13 feet wide and 7 feet long. The total excavation in the pit is about 17 cubic yards.

The regular interval of guns in battery is preserved if the ground admits of full development, otherwise alternate or all intervals are reduced one-half. If water or rock is found near the surface, or the field of fire is sacrificed by sinking the gun, the epaulement must be constructed on the surface of the ground from material excavated in the vicinity. Gun-pits are masked by placing them in the rear of some natural screen, as a low hedge, or growing grain; in the absence of natural screens artificial ones may be constructed. A thin embankment connecting the lements will also make them less conspicuous. The

limber chests may be removed from their carriages and placed in the gun-pit close to the epaulement as shown in Pl. V, Fig. 36, or in chambers excavated in the solid earth underneath the epaulement. In dry sandy soil, the cloud of dust blown from the epaulement neutralizes the advantages of smokeless powder in concealing the location of the guns; in such a soil it is better to conceal the guns simply by masks. Sunken roads, embankments, ravines, and ridges are often utilized in the field to secure cover for artillery.

In deliberate intrenchments the guns are fired over epaulements or parapets, or through openings in them. The former is called *barbette*, and the latter *embrasure* fire.

Barbettes.—The height of the axis of the trunnions of a field-gun is 43½ inches; this permits the gun to be fired with the usual angles of depression over a parapet about 3 feet high. If the crest of the parapet greatly exceeds this height, the gun is mounted on a *barbette* or *gun bank* [Pl. V, Fig. 39], which is simply a terrace constructed in rear of the epaulment. The upper surface of the barbette is horizontal and is made 12 to 15 feet wide and 18 to 20 feet deep. The side slopes of the barbette are $\frac{1}{1}$, and a ramp, 8 feet wide with an inclination of $\frac{1}{6}$ or $\frac{1}{8}$, forms a communication between the platform of the barbette and the parade. Head-cover for the cannoneers against the oblique fire of the assailant may be secured by the construction of rifle-proof bonnets between the guns. Where several guns are placed along the same front of a work they should be placed at intervals of 15 feet, if exposed to front fire only, and 30 feet, if exposed to oblique or enfilade fire; the latter interval admits of the construction of traverses between the guns. For siege-guns the surface of the barbette is 5 feet below the interior crest. The advantages of barbette mounting are simplicity of construction, and a wide field of fire; its defect is the exposure of the cannoneers to the view and fire of the enemy.

Embrasures.—[Pl. V, Fig. 40.] The nomenclature of an embrasure is as follows:

ABCD, the opening in the interior slope, is the *throat.*

BCEF, the bottom of the embrasure, is the *sole.*

ABEG and CDHF, the side slopes, connecting the sole with the superior slope of the parapet, are the *cheeks.*

BC, the lowest line of the throat, is the *sill.*

The angle made by EB and FC is the *splay.*

IK is the *directrix.*

The width of the throat is about 20 inches on the sill; its shape is trapezoidal or rectangular. The inclination of the sole, determined by the desired vertical field of fire, is usually that of the superior slope. If the side EF has a greater elevation than BC, the embrasure is *counter-sloping.* The splay is determined by the desired horizontal field of fire. If the directrix is perpendicular to the interior crest in the trace, the embrasure is *direct*, otherwise it is *oblique.* The cheeks are warped surfaces which are nearly vertical at the throat, and have an inclination of $\frac{1}{1}$ to $\frac{3}{1}$ at the exterior crest; the cheeks are revetted with sods, gabions, fascines, etc., and if the soil is light may be covered with raw hides. For siege-guns the embrasure is widened into an elliptical recess at the muzzle of the gun to reduce the effect of the blast on the cheeks. To thoroughly protect the cannoneers, the sill of the embrasure of a field-gun should be 3 feet below the interior crest. The upper part of the parapet between two embrasures is called a *merlon.* The interval between guns firing through embrasures is the same as that between barbette guns. Embrasure fire has the advantage of shielding the cannoneers from direct and oblique fire; it has the defects of a restricted field of fire, of indicating to the assailant the probable armament of the work, and of weakening the [illegible]t. The second defect is partially removed by mask-[illegible]mbrasure on the outside with brush, or by closing [illegible]at with sand-bags or shields. If the directrix is [illegible]e parapet is modified as shown in Pl. V,

Fig. 41, so as to strengthen the parapet to resist a shot striking the oblique cheek of the embrasure.

Separation of Artillery and Infantry.—The attack of every fortified position is begun by an attempt on the part of the assailant's artillery to overwhelm with its fire the artillery of the defender. As it is deemed important to shelter the defender's infantry from this fire, his guns are, as a rule, no longer placed with the infantry in the redouts, but are placed in separate batteries. The guns may be scattered and placed in separate pits, or two or more may be combined in a battery for barbette or embrasure fire. These batteries are called *sunken*, *natural site*, or *elevated* batteries, according as the platform is below, upon, or above the level of the parade. The kind of battery which should be constructed at any point depends upon the relative values of concealment and command, and upon the topographical features of the site. In special situations, as a single redout guarding a defile, it will still be necessary to place the guns in the work so as to more effectually guard them; care should be taken that the construction of the artillery epaulements does not interfere with the effective infantry defense of the work. As a rule the guns of deliberate intrenchments are mounted, as upon the battle-field, in barbette, for the purpose of securing a wide field of fire; occasionally they will fire through embrasures when only a limited field is required.

Casemates.—As field-artillery now uses shrapnel and torpedo shells, and modern armies are equipped with howitzers and mortars for curved and high-angle fire, it is almost impossible to serve any gun exposed to concentrated artillery fire, unless the cannoneers are protected by covered shelters. Such protection is absolutely essential for guns mounted in redouts, for these cannot be masked from the enemy's view. A shelter which protects a gun and its cannoneers from high angle fire, as well as from direct and curved fire, is called a *casemate*. A block-

house, similar to the one whose section is shown in Pl. VII, Fig. 53, can be utilized as a casemate.

Gun-recess.—It is always desirable to conceal and protect each barbette gun when not in action; for this purpose a trench called a *gun-recess* is excavated immediately behind the parapet at the side of the barbette, as shown in Pl. V, Fig. 39. It communicates with the parade by means of ramps. Gun-recesses should always be constructed in sunken or natural site barbette batteries, as the guns can not be concealed by the parapet.

Platforms.—Guns firing through or over a parapet require firm platforms to keep the axis of the trunnions at a constant elevation above the crest of the parapet or the sill of the embrasure. The simplest platform is made of three squared logs or thick planks which are firmly pegged in place to support the wheels and the trail. The gun may be checked in its movement to the front or rear by a pile of sand-bags. This platform is serviceable only for a gun firing constantly in one direction; if a wide field is desired, a plank platform is constructed. This consists of five or more logs or *sleepers* laid perpendicular to the parapet and covered transversely, to a depth of three inches, with boards or planks firmly spiked to the sleepers. The platform has a slight upward slope to the rear to assist in checking the recoil; a 6-inch beam or *hurter*, which is spiked to the platform transversely, prevents the gun from moving too far to the front. The size of the platform for a field-gun is about 10 by 12 feet, for a siege-gun 12 by 14 feet.

In our service, specially constructed platforms are issued by the Ordnance Department with all siege-artillery. For guns and howitzers these are formed of rows of sleepers, parallel to the parapet, covered by two layers of 3-inch planks, placed at right angles to each other; the urface layer is parallel to the sleepers.

CHAPTER VI.

TRAVERSES, SPLINTER-PROOFS, BOMB-PROOFS, MAGAZINES, BLOCKHOUSES, AND DITCH DEFENSES.

Traverses.—A traverse is a mound of earth which is utilized to intercept infantry and artillery fire; if constructed to intercept reverse fire it is called a *parados*, and if constructed to localize the action of exploding shells and shrapnel, it is called a *splinter-proof traverse.* If a line of shelter trench is exposed to enfilade fire, a short traverse may be constructed by making an offset in the trench, or a long traverse by excavating an auxiliary trench and throwing up the parapet upon the side from which the fire is received [Pl. VI, Fig. 43]. In deliberate intrenchments traverses to intercept enfilade fire are usually connected with the parapet as shown in Pl. VI, Fig. 44; in which the horizontal lines in the figure are the exterior crest, the interior crest and the foot of the interior slope of an artillery parapet exposed to the enfilade fire of a battery on the right.

The least thickness of a traverse to resist the direct fire of field-artillery is 8 to 10 feet, and to resist small arms and the fragments of shell and shrapnel 2½ to 3 feet. The greater the height of a traverse, the more extensive is the area which it shelters; in practice however it is found advisable to limit the height to an elevation of 2 feet above the parapet. A traverse which projects well above the parapet gives an excellent target for the assailant's artillery. The length of a traverse is determined by the area which it is desired to protect; to cover shelter-

trenches from enfilade fire, a traverse extends from the parapet to the rear of the trench; to shelter field-guns a traverse extends from the parapet to the rear line of the gun platform. The top of a traverse is slightly rounded to shed the rain-water; the side exposed to direct artillery fire is made the natural slope of the earth or even less; the other sides may be revetted to economize the interior space. In Pl. VI, Fig. 44, the top is made of two plane surfaces like an obtuse gable; the exposed slopes are $\frac{1}{4}$ and the retired slope $\frac{3}{4}$.

A *splinter-proof traverse* is only 3 feet thick and may have all its sides revetted. When it is placed between the guns of a battery or along an infantry parapet, its axis is usually perpendicular to the interior crest, and a passage-way is left between the parapet and the traverse. Two tiers of gabions with two rows of gabions in each tier, is the ordinary construction of a splinter-proof traverse. In a field fortification in which a continuous parapet incloses an area, a parados must be constructed to protect the troops in the trench along the gorge or rear face from the reverse fire of projectiles coming over the front face. This traverse is usually made in the form of a parapet, as shown in Pl. VI, Fig. 49, so that it may be used as a second line of defense when the main parapet is captured.

Covered Shelters.—The increased range and accuracy of artillery fire, the employment of torpedo shells, and the introduction of howitzers and mortars into the field armament, have necessitated an extensive employment of shelters with overhead cover. In an intrenched position, these covered shelters are located in auxiliary trenches, in sunken roads, behind embankments, and on the reverse slope of hills, where they are concealed from the view of the assailant and are protected from direct fire; in deliberate field fortifications they are under the parapet, and sometimes under the traverses and parados. They are classed as *splinter-proofs* and *bomb-proofs;* the former are proof against rifle fire and the fragments of shell and

shrapnel, and the latter against the curved and vertical fire of field- and light siege-guns, howitzers and mortars. The floor space of a covered shelter is proportional to the number of men and the manner in which they are to be accommodated. German engineers make approximately the following allowances:

	Square Feet required by each Soldier. With Equipment.	Without Equipment.
Standing crowded.....	4	2
Standing at ease or sitting....	6	4
Lying down crowded.....	—	7
Lying down at ease.....	—	10

These spaces do not include the necessary passageways. English engineers allow 18 square feet per man for long occupation.

Splinter-proofs.—To protect a splinter-proof from the direct impact of shells, the roof may be given a slope to the rear approximately equal to the maximum angle of fall of field-gun shells at battle ranges, which is $\frac{1}{5}$. Two inches of wood are sufficient to intercept the fragments of shell and shrapnel from field-guns, and four inches to intercept those from siege-guns, when the roof is protected from direct impact. A thin coating of earth is usually added to decrease the effect of explosion and the scoring of the fragments. Pl. VI, Figs. 45, 46, 47, and 48, indicate some of the methods of constructing splinter-proofs for hasty intrenchments. The roofs extending across the kneeling trench are doors, gates, boards, etc., which are thrown off when the long range infantry and artillery fire cease. In deliberate fortification, splinter-proofs are ordinarily lean-tos constructed in the rear of a traverse.

Bomb-proofs.—To resist the curved fire of field-guns, the roof of a bomb-proof should consist of at least 6 inches of squared or round timber covered with 3 feet of earth; a double thickness of earth and timber will resist light siege-guns, field howitzers, and mortars. Bomb-proofs may be intended for the temporary occupation of troops,

during an artillery attack or bombardment upon the field of battle, or they may be intended to protect the garrison of a field fortification not only from fire, but also from the weather, during a long occupation of the work. For temporary occupation they are of simple construction and of small dimensions similar to the splinter-proof shown in Pl. VI, Fig. 48; this is a type of a bomb-proof which may be constructed by covering a trench. The ends are protected by a splinter-proof wall. For prolonged occupation, care is taken to provide for the comfort and health of the troops, by giving the bomb-proofs ample dimensions, and making them proof against the effects of the weather.

In the construction of the fortifications around Washington during the Civil War, carefully constructed bomb-proofs, as shown in Pl. VI, Fig. 49, were placed in the parados of each fort. The floor was sunk 4 feet below the level of the parade, and the excavation was made wide enough to provide a trench 4 to 6 feet wide, in rear of the bomb-proofs. The roof was supported by two frames, each consisting of a ground-sill, a cap-sill, and uprights of 12 by 12-inch timbers roughly squared. The uprights of the frame were placed 4 feet apart, and were 9 feet long in the rear frames, and 7 feet in the front ones. The frames were placed 12 feet apart, and were covered by 12-inch roof-logs placed close together. To make the roof water-tight, the logs were covered with two layers of boards each coated with a hot composition of coal-tar and resin. The front of the bomb-proof was closed with inclined posts which supported a layer of poles. The posts were 6 to 8 inches in diameter, and the poles 2 to 4 inches. The rear frame was boarded, to protect the interior from the weather, and the bomb-proof was lined with one-inch boards, not shown in the plate. The frame was anchored to the parapet, by allowing every alternate roof-log to project 8 feet into the parados, where it was fastened to an anchor-log, which was held in place by vertical pickets. The bomb-proof was protected against vertical fire by an

earth covering of 6 feet, and against direct fire by an earth covering of 10 feet.

The bomb-proofs of the Turkish army about Plevna were of more simple construction. They were usually 6 to 6½ feet high, 6 to 13 feet wide, and consisted of pillars formed of trunks of trees, in the forks of which rested the logs which supported the roof. The roof was made of logs in close contact and a layer of straw or sods to support the earth covering. The depth of this covering varied from 1 to 4½ feet. The bomb-proofs were constructed within the redouts, under the parapet and under the traverses, and upon the exterior, in the counterscarp. Railway rails make an excellent substitute for timber in the construction of the roofs of bomb-proofs. In the defenses of Dresden, constructed by the Germans in 1866, the bomb-proofs were made of concrete.

In a deliberately constructed redout the bomb-proofs for the men on duty should be under the parapet; for the reserves and general garrison, in the main parados.

Ammunition Recesses and Magazines.—An ammunition recess is simply a revetted chamber open in the rear, excavated under the parapet or in a traverse, for the temporary storage of ammunition [Pl. V, Fig. 39]. Recesses for rifle ammunition are made at intervals along the parapet, about the level of the banquette or above it. The ordinary ammunition box, which is 20 inches long, 13 inches wide, and 8 inches deep, and contains 1000 rounds of ammunition, may be used for this purpose. The lid being removed, the box is set on edge, in an excavation made in the front slope of the trench. At Plevna, five hundred rounds of reserve ammunition were placed near each man.

For artillery, recesses are made of sufficient size to hold one or more of the limber chests. A field-artillery chest with its handles, can be enclosed in a space 54 inches by 30 inches by 24 inches; by removing the handles, these dimensions become 50 inches by 30 inches by 15 inches.

A recess for two tiers of chests should be about 5 feet high.

A magazine differs from an ammunition recess only in affording more complete shelter to its contents. The chamber is protected against direct fire by an earth cover 16 feet thick, against vertical fire by a bomb-proof roof, and its entrance is protected by a splinter-proof. Recesses and magazines for artillery ammunition are made by constructing bomb-proof covers over a trench, or by constructing a chamber in a traverse or under the parapet, using gabions or fascines to support the sides and roof [Pl. VI, Fig. 50]. In the defenses of Washington, the magazines were constructed of frames, in a manner similar to that described in the construction of bomb-proofs [Pl. VI, Fig. 51].

Blockhouses.—A blockhouse is a defensible barrack, in which the garrison is protected from the weather and the enemy's fire; and from which, the garrison can sweep with its fire all the ground in the vicinity. Blockhouses are used as separate works for the defense of mountain passes, for the protection of the communications in the rear of the army, as isolated posts against an enemy not provided with artillery, and as citadels or keeps in field-works. (A *citadel* or *keep* is an interior intrenchment, within a fortification, to which the garrison retires to prolong the defense, when driven from the main parapet.) They may be defended wholly by infantry, by infantry with machine guns, or by artillery. For long occupation the interior height of the blockhouse should be at least 6½ feet, and 18 square feet of floor space should be allowed for each man; in the blockhouses constructed in the defenses of Washington the height was 10½ feet and the floor space, per man, was 33 square feet. The roof must be made fire-proof, the interior properly drained, and the garrison provided with an ample water-supply.

A blockhouse to resist infantry fire may be made of an ordinary unplastered frame building, as shown in Pl. VII,

Fig. 52, by removing boards so as to leave a horizontal opening or loophole, about 3 inches high and 4½ feet above the floor, entirely around the building. Below this opening the wall is made bullet-proof by excavating a trench around the building and throwing the earth against the walls. Head-cover is secured by nailing to the studding above the loophole thick planks or a trough 8 inches wide and 1½ feet high, which is rendered bullet-proof by a filling of broken stone or gravel. The roof should be of tin or some other fire-proof material. The walls of a blockhouse may also be of logs, placed horizontally or vertically, or of stone, railway rails, etc.

If the blockhouse is liable to be struck by artillery projectiles, as the citadel or keep of a field-work, the roof is made bomb-proof, by a layer of earth three or more feet thick, placed over the roof-logs, as shown in Pl. VII, Fig. 53; in the blockhouses constructed during the Civil War, this layer of earth was covered by a shingle roof. The vertical distance between the loopholes and the roof is made as small as possible, and the roof-logs project two or more feet, so as to protect the loopholes from artillery fire.

Formerly it was customary to make the blockhouses of two or more stories, to secure a greater amount of fire, and to remove dead spaces and sectors without fire. At present this is not considered advisable; an additional tier of fire is secured by surrounding the blockhouse with a trench, as shown in Pl. VII, Fig. 52, having an underground communication with the house; the dead spaces and sectors without fire, close to the house, are removed by making the blockhouse in the form of a Greek cross. (A *sector without fire* is the sector in front of any salient angle of a fortification which cannot be swept by the front fire of the adjacent parapets.) A blockhouse is usually provided with a cupola, from which an extended view may be obtained over the surrounding country. Blockhouses of heavy timber, arranged for infantry and artillery defense, were extensively used in our Civil War to protect the rail-

ways in a hostile country. In the war with the insurgents in Cuba, the Spaniards used small square or hexagonal blockhouses, similar to Pl. VII, Fig. 52, in defensive relations with each other, for the lines of defense about the cities and for the trochas which extended across the island. Blockhouses which can be taken apart for transportation, have been used by the French army in Algeria.

Ditch Defenses.—One of the requisites of an efficient obstacle is that it shall not give cover to the assailant. The ditch of a field-work constructed with the ordinary profile, and without reëntrant angles in the trace, affords cover to the assailant from the fire of the defender, and does not comply with this requisite. Although with modern magazine-rifles this defect is not so serious as formerly, it may be advisable to remove the dead space in the ditch of an isolated field fortification, which receives little or no support from adjacent works. Without modifying the trace, this may be done by the use of the triangular profile, or by the construction of special works for sweeping the ditch with infantry or machine gun fire.

Caponiers.—A caponier is a small blockhouse constructed in the ditch itself, adjacent to the scarp, so that its fire may be delivered along the ditch. It is usually placed at a salient angle, so that the ditch in front of the two adjacent faces may be swept from it. The top of the bomb-proof roof is kept at or below the level of the counterscarp, so that the caponier may not be destroyed by the enemy's artillery; the interior is at least $6\frac{1}{2}$ feet high. To prevent the assailant from using the caponier as a bridge to cross the ditch, it is either separated from the counterscarp by an auxiliary ditch or the top is made impassable by the use of barbed wire. The caponier may be entered by a rifle-proof door from the ditch, or by an underground passage connecting it with the parade.

Counterscarp Galleries.—A counterscarp gallery is a bomb-proof chamber excavated behind the counterscarp at a salient of a redout. The side, facing the ditch, is closed

by a loopholed stockade through which fire may be delivered along the ditch. The entrance to the counterscarp is a rifle-proof door opening into the ditch. The width of a caponier or counterscarp gallery is determined by the kind of firearm which is used in the defense. The pistol, rifle, and machine gun are all available for this purpose.

CHAPTER VII.

REVETMENTS, TRACE, AND GARRISON.

Revetments.—A revetment is any covering placed upon a slope of earth, to enable the material to stand at a greater inclination than its natural slope. The principal uses of revetments are to increase the amount of protection given by the parapet against curved or shrapnel fire, to enable the defenders using it to fire with greater ease, and to decrease the amount of space occupied by the parapet and interior works. Every revetment should if possible be protected from direct artillery fire, and the revetment of the interior slope near its top should be made of material which will not splinter nor throw dangerous fragments when struck by grazing projectiles. While the time required for their construction will ordinarily limit the use of revetments to deliberate intrenchments, the more simple kinds may be advantageously employed in the construction of shelter-trenches upon the key points of a position, which are exposed to artillery fire. Revetments may be constructed of brush, hurdles, fascines, gabions, sandbags, sod, rubble, casks, planks, timber, etc. Most revetments should be firmly anchored to the mass of earth whose slopes are protected.

Brush.—A brush revetment, Pl. VII, Fig. 59, for the interior slope, is made by driving strong stakes into the banquette tread to retain the brush, which is packed behind them. The stakes are at least 2 inches in diameter; they are spaced from 1 to 1½ feet, and are driven about one-third their length into the ground. The tops of the stakes are

connected by a horizontal strip which is securely anchored to the parapet with withes or wires. The brush is packed longitudinally behind the stakes, the revetment being carried up with the earth filling behind it. This revetment is easily constructed, but is weak and perishable. Boards or rails may be used instead of brush to retain the earth. *Withes* are flexible rods, used to replace rope or wire in binding materials in the field. The best withes are made of hickory or hazel rods, 5 feet long and $\frac{1}{2}$ to $\frac{3}{4}$ inches in diameter, which are freed from all twigs. To make a rod flexible, the thick end is placed on the ground and firmly held by one foot, while the rod is well twisted.

Gabions.—A wicker gabion is a cylinder of strong basket-work open at both ends. Its usual dimensions are 2 feet in diameter and $2\frac{3}{4}$ feet in height; its weight is 36 to 56 pounds. The method of construction is shown in Pl. VII, Figs. 54 and 55. A gabion is made by driving into the ground, on the circumference of a circular, notched board, called a *gabion form*, seven to nine pickets with butts alternately up and down. Each picket is $3\frac{1}{2}$ feet long and 1 inch in diameter. The form is then raised 1 foot from the ground, and is held in place by a rope, which is passed around the pickets just below the board, and drawn tight with a rack-stick. The *web* or *watling* of the gabion is made by weaving or *waling* rods around the pickets, beginning at the form. The butts of the rods are placed in adjacent intervals between the pickets, and the rods themselves are woven about the pickets and about each other. The web may be made by weaving with two or three rods; and the rods may be passed in and out of the pickets alternately, or they may be passed outside of two pickets and inside of the third. Each rod is less than 1 inch thick at the butt, and is freed from all twigs. In weaving, the web is occasionally hammered down with a mallet to make it compact. It is completed, 3 inches below the tops of the stakes, by one layer made of two rods passed alternately in and out of each picket; this

method of weaving is called *pairing*. The web is completed by binding it together with withes or wires, which are drawn through it parallel to the pickets. When the upper part of the gabion is completed, the pickets are sawed off, and the gabion is turned over. The form is removed, and the weaving continued until it has the proper height. The gabion is completed by driving a carrying-rod through the web across the gabion. A gabion may also be made without a form by simply driving the stakes into the ground on the circumference of a circle. With a form two men can make a gabion in one hour; without a form three men are necessary.

Tyler's sheet-iron gabion is formed of a sheet of galvanized iron 3 feet wide and $6\frac{1}{8}$ feet long, which is bent into a cylindrical form and fastened by wires driven through holes in the edges of the sheet; it weighs 26 pounds. A *hoop-iron gabion* is one in which the basket-work is made of hoop-iron rings, woven about the pickets; its weight is about 30 pounds.

A *gabion revetment* is constructed by placing the gabions in a row on the proper line, partially filling them with earth, and then canting them so as to give the proper inclination to the slope. The slope may also be given by half-burying a fascine at the bottom of the interior slope. When the slope is adjusted the gabions are filled with earth. If a height of $4\frac{1}{2}$ feet is desired, the usual height of a revetted infantry parapet above its banquette, a row of fascines may be placed on top, but it is better to finish the interior slope with sods, as a shot striking the fascine would injure a long stretch of parapet. To revet a high slope each tier of gabions is capped with two rows of fascines. In high revetments it is advisable to anchor each tier of gabions to the parapet. The stability and easy repair of a gabion revetment makes it applicable to all kinds of work. In the construction of the defenses of Washington it was found that if the wicker gabions were

[illegible] with well-rammed turf, the grass soon enveloped the

basket-work and formed a revetment which was very durable even after the gabions had decayed. The hoop-iron is a very convenient form of gabion, but cannot be used if the soil is loose or sandy.

Fascines.—A fascine is a cylindrical bundle of poles, about 9 inches in diameter and 18 feet long, bound with wire or withes; the poles are from 1 to 2 inches thick at the butt. The wires are so placed that it can be cut in 6 or 9 feet lengths. The method of construction is shown in Pl. VII, Figs. 56 and 57.

The fascine is made in a *cradle*, 16 feet long, composed of five fascine trestles. Each *trestle* is composed of two stakes, 6½ feet long and 3 inches in diameter, driven into the ground in the form of a letter X, and fastened together with rope or wire. The cradle should be horizontal and the upper angle of the trestle about 2½ feet above the ground. The rods are laid in the cradle, butts alternating, so as to project a little more than one foot beyond each end of the cradle; care is taken to make the fascines of uniform diameter. The circumference of the fascine is tested by compressing it with a fascine choker and measuring it with a tape. The *choker* is made of two wooden levers each about 2 inches thick and 4 feet long, connected, at points 1½ feet from their ends, by a chain 4 feet long. The manner of using it is shown in Pl. VII, Fig. 57. If the circumference be of the proper length, the fascine is bound close to the choker, with withes, rope, or wires. The first binding is placed 3 inches outside of the end trestle, and the others at intervals of 1½ feet. The fascine is completed by sawing it off 9 inches beyond the extreme bindings.

To fasten it in place each fascine is provided with six pickets 3½ feet in length and 1⅛ to 1½ inches in diameter. To make a *fascine revetment*, a row of fascines is laid in a groove, 3 inches deep, at the foot of the interior slope, and firmly pegged to the earth. Upon it is placed a second row, breaking joints with the first row, and fastened to it and to the parapet with the pickets. This process is con-

tinued to the top of the revetment. Every third or fourth row should be securely anchored to the parapet. The fascine revetment is not so stable as the gabion revetment, and requires more material; to offset these defects larger material may be used in its construction. Fascines are very useful in the construction of steps.

Hurdles.—A continuous *hurdle revetment* is similar to the brush revetment; the brush being replaced by a web of rods. The rods are about 1 inch in diameter at the butts, and are cleared of all twigs. The anchoring-wires are wrapped not only around the stakes, but also around five or six of the upper rods of the hurdle so as to hold it in place. *Hurdles* [Pl. VII, Fig. 60] are similar webs, which are transportable; they are usually made 6 feet long and 4 feet wide. Hurdles are used in the construction of revetments, roofs, covered shelters, and floors of bridges. In the construction of a revetment, the hurdles are placed side by side, fastened together, and anchored to the parapet with wires. The hurdle revetment is stronger and more durable than the brush, but is still weak and perishable.

Sand-bags.—A sand-bag is a canvas bag 33 inches long and 14 inches wide, which, when filled for use in revetments, contains about one-half of a cubic foot of sand, and weighs about 60 pounds. A revetment is constructed by laying these bags alternately as headers and stretchers, or as headers alone; the top course should be headers. The openings of headers and the seams of the stretchers should be in the parapet. Sand-bags give no splinters, can be readily transported, and are used for the entire parapet in rocky or marshy soil when no other material is available.

Sods.—The sods are cut in blocks 18 inches long, 12 inches wide and 4 inches thick. They are laid grass side down either alternately as headers and stretchers, or one tier of headers to three or four of stretchers. Thin pegs 6 or 8 inches long are used to unite the tiers, and the revetment is finished by a layer with the grass side up. The sod revetment is difficult to construct, and requires

much time and labor. It forms the very best revetment and is very durable.

Rubble.—When loose rock is found on the site, a rough rubble wall may be constructed as a retaining wall. The upper part of the parapet should be of earth free from stone.

Casks.—Casks filled with earth may be substituted for gabions in the construction of revetments, but are more easily destroyed by artillery fire.

Plank.—A plank revetment is made by planting short posts in the banquette, capping them with strong timber and anchoring this framework to the parapet. The planks are placed in a horizontal or vertical position against this frame, and support the parapet. If placed vertically, a riband piece may be fastened to the posts, near the bottom, to support the planks. Planks are also used for revetting steps.

Timber.—A very durable timber revetment was constructed in the defenses of Washington [Pl. VII, Fig. 58]. It consisted of posts from 4 to 6 inches in diameter, cut into lengths of $5\frac{1}{2}$ feet, and set with a slope of $\frac{6}{1}$ in close contact. The foot of each post rested on a 2-inch plank, buried 2 feet under the banquette tread. The posts were capped with a 6-inch timber roughly squared. Anchorties of wood were dovetailed into the capping, and into an anchor-log buried in the parapet.

The Trace.—The trace of a field fortification is the projection of the lines of the work, such as the crest and foot of each slope, upon the plane of reference, usually the plane of site, or upon the site itself. In field fortification the directing line is the horizontal projection of the interior crest; it is sometimes called the *sub-crest* and determines the class to which the work belongs. The trace of a field fortification should, if possible, be so adjusted to the site that the defenders have an extended field of fire free from obstructions and dead angles; that the ground over which the assailant is constrained to make his attack is

thoroughly swept by front, flanking, and cross fires; and that no line of the fortification is exposed to enfilade or reverse fire. It will rarely be possible to locate a field fortification, especially in hasty intrenchment, so that all these requirements are fulfilled. It can, however, be so placed that the foreground is clear, or can readily be cleared, to the limit of accurate rifle fire; that ground which cannot be swept by front fire may be swept by oblique fire in which the angle of obliquity does not exceed 30°; that ground which cannot be swept by front or oblique fire may be swept by flanking or cross fire. In thus tracing the fortification, it may be necessary to expose lines of the work to enfilade or reverse fires; such lines must be protected by traverses.

Classes of Field-works.—In order to facilitate the description of small field fortifications, they are divided into three classes: open, half-closed, and closed *field-works.* An *open work* has a parapet on the side of the assailant only, and is wholly unprepared to resist an attack from the rear; it depends upon adjacent parts of the line of defense to protect its flanks from being turned. A *half-closed work* has a parapet on the side of the assailant only, but its rear is closed by an obstacle which temporarily protects the defender from the assailant when the work is surrounded. A *closed work* has a parapet upon all sides; the parapet is usually weaker in the rear than in the front.

To adjust the fortification to the site, use is made of various geometrical forms of traces to which names have been applied.

Lines.—The line [Pl. VIII, Fig. 61] is an open work and is the trace which is usually adopted for the shelter-trench of a company or small battalion on the battle-field. The ends may be drawn back to give cross fires in front of the trenches of the adjacent troops, and sweep the intervals between them. A long line may be *indented* [Pl. VIII, Fig. 62], to avoid enfilade fire, when the prolongation of a straight line intersects a site which may be occupied by

the assailant's batteries, or to secure flanking fires along the line. Reserves are sheltered in column of companies or platoons, by successive lines of covering trenches as shown in profile in Pl. I, Fig. 7.

Redans.—The redan [Pl. VIII, Fig. 63] consists of two *faces* AB and AC which make an angle of about 60° with each other. The angle A is called the *salient* angle, its bisecting line AD the *capital*, and the line BC the *gorge*. The redan is usually an open or half-closed work, and is employed to secure flanking fires along a straight line of fortification. As no fire can be delivered from a redan along the line of the capital, it should be so directed that the foreground in its prolongation is either an impassable obstacle, or is well swept by flanking or cross fires from other parts of the line of defense. To secure fire along the capital the redan is sometimes *blunted* as shown by the full line in Pl. VIII, Fig. 64. Any straight line thus replacing a salient angle is called a *pan-coupé*. A *swallow-tail*, or *priest-cap*, is a blunted redan, terminated by a re-entrant angle instead of a right line, as shown by the broken lines in Pl. VIII, Fig. 64.

Lunettes [Pl. VIII, Fig. 65].—A lunette consists of two *faces* AB and AC and two *flanks* BD and CE. The angle at A is the *salient* angle, the angles at B and C are the *shoulder* angles. AF is the *capital*, and DE is the *gorge*. The lunette, like the redan, may be an open or half-closed work. All the angles of a lunette are made at least 120°, so that every part of the foreground is swept by front or oblique fire. When strong fire to the front is desired, the salient angle is made about 150° or the faces are replaced by a straight line joining the shoulder angles. Pl. VIII, Fig. 66, is an open lunette adopted by the French engineers as the type of work to be constructed for a company of infantry, which is to hold a key-point of a battle-field. The main faces and flanks are trenches to resist field-artillery shells, and arranged to deliver a strong fire to the front; the returns AB are kneeling trenches to

deliver fire to the rear in case the flanks are turned; and the gorge CD is a complete shelter-trench in which the reserves are sheltered and from which they can deliver fire to the front into the lunette, in case it is taken by the assailant. Three platoons of the company occupy the front line and one is kept in reserve.

Redouts.—A redout is any closed field-work in which all or nearly all of the angles are salient angles. The trace is usually some modification of the lunette, in which the depth is one-third to one-half the front. It thus affords a poor target to the assailant's artillery, but yet admits of the construction of a parados for the protection of the defenders of the gorge and the reserves. Pl. VIII, Fig. 67, is the type of hastily constructed field redout for an infantry garrison of one company, which has been adopted by the German engineers for strengthening a key-point upon the battle-field. Redouts are usually employed only in positions in which a small body of troops desires to make a very vigorous defense. They are made to conform to the topography of the site, so as to be inconspicuous, and have a development of interior crest between 150 and 200 yards.

In deliberate fortification or intrenchment, redouts are constructed with profiles to resist siege-gun fire on all the exposed sides, and to resist field-gun shells on all the interior sides. They are well provided with bomb-proofs to resist the curved and high-angle fire of light siege-artillery.

Forts.—A fort is a closed field fortification in which the angles are both salient and re-entrant. The object of this form is to have each face flanked by the fire of some other face, so that the ditches may be swept without constructing caponiers or counterscarp galleries. The ordinary forms are the star and the bastion. In the *star* fort, Pl. IA, Fig. 7*d*, the adjacent *faces* AB, BC, etc., flank each other; in the *bastion* fort, Pl. IA, Fig. 7*e*, the *flanks*, BC and DE, flank the *faces*, AB and EF, and the *curtain*, CD. In laying out a bastion fort, the

tangent of the *diminished angle*, BAF, is usually made one-third, and the curtain is made about one-third of the exterior side, AF. As forts require more time and labor to construct than redouts, and as their parapets are more difficult to protect from enfilade and reverse fires, they are now rarely constructed in field fortification. The distinction between redouts and forts given above is not rigidly adhered to; the term redout is also employed to describe any closed work which has a weak garrison and armament, in contradistinction to a fort which has a strong garrison and armament.

Lines of Fortification.—The term *line* is also used to signify a chain of fortifications of considerable extent; as the fortifications surrounding a city or extending along the front of an army. The line is a *continuous line* when it consists of a parapet practically continuous and a ditch of equal strength throughout; it is a *line with intervals* when it is made up of a series of strong positions connected by weak lines, as a series of redouts connected by shelter-trenches. Continuous lines are objectionable, as they admit only of passive defense and must ordinarily be abandoned when any part of the line is captured; lines with intervals admit of active defense and afford strong points of resistance, at which an assailant's advance may be checked, should he succeed in capturing one point of the line.

The Gorge.—If the gorge of a half-closed field-work is so situated that it cannot be reached by the assailant's artillery fire, it may be closed with a palisade, or a bullet-proof stockade; otherwise it should be closed by an obstacle difficult to destroy by artillery, as an abatis or a wire entanglement. A passage for communication is made through the gorge of half-closed and closed works. This passage should be 4 feet wide for infantry, and 7 feet wide for artillery. In half-closed works this passage is barred by a cheval-de-frise, or a strong gate; in strong closed works in addition to these there is usually constructed in

the interior a traverse, or on the exterior a redan, to intercept fire which might be directed through this passage, as shown in Pl. VIII, Fig. 65. The passage of a deep ditch is usually effected by means of bridges or ramps. A simple bridge is one in which the roadway bearers rest upon a wooden trestle placed in the middle of the ditch. Rolling and other movable bridges are sometimes recommended, but are rarely constructed.

Garrison of a Field-work.—From one pace to one yard is usually allowed for every rifle in the firing line of a shelter-trench; the length of trench occupied by a company or by a battalion will therefore be as many paces, or yards, as there are men who are to be deployed upon the firing line in single or double rank, exclusive of officers and file-closers. The length of a covering trench is determined in a similar way by the number of men in the supports or reserves. In the French lunette for a single company, two men per meter are allowed for the faces and flanks, and one-fourth of the garrison is kept along the gorge as a reserve. In the closed field redout, the Germans have one man per meter of interior crest in the firing line, and one-fourth of the garrison as a reserve; the English allow one man per yard of the crest in the firing line, one-half as many along the main faces as supports, and one-eighth to one-quarter of the garrison as a reserve. Any of the above rules provides a satisfactory garrison for defense. For deliberate fortifications, the rule heretofore generally applied is two men per yard along the main faces, and one man per yard along the gorge; although the magazine-rifle has strengthened such a garrison, the number is not ordinarily reduced, as provision must be made for sickness and other causes which might temporarily decrease the strength of the garrison.

CHAPTER VIII.

DEFENSE OF BUILDINGS, VILLAGES, CITIES, WOODS, AND DEFILES.

Buildings.—In operations in which infantry or cavalry alone take part, as in some advance-guard and outpost actions, and in the attack and defense of villages and cities, well-constructed buildings, properly arranged for defense, may act as supporting points of an engagement. By a well constructed building is meant a masonry building with walls about 2 feet thick, and with a roof of wrought iron, tin, or tile which cannot be readily set on fire. The building should, alone or in conjunction with other similar buildings, be capable of holding a garrison large enough to make its fire felt by the assailant. If concealed from the view of the enemy's artillery, defensible buildings replace small redouts in lines of investment, in the lines of defense of a strategic position, and as points of support upon a line of battle.

Protection against assault and infantry fire is secured by removing the window-sashes and doors, and closing all openings with bullet-proof shields. The cellar windows are concealed by a bank of earth. In the ground floor and upper stories, the windows and doors are closed with bullet-proof shields made of beams, or of bags, boxes, casks, and chests of drawers filled with earth or gravel. Openings are left near the top of each window and door for light and ventilation. If the material on hand does not admit of making shields which entirely close each door and window, the shields should extend to a height of at least 4½ feet above the floor, and the remainder of the aperture be

masked with boards. Loopholes, at intervals of a yard, are constructed in every wall and shield in each story of the building. The splay of the loopholes is arranged so as to remove, as far as possible, all dead angles and sectors without fire, in the vicinity of the building.

To secure additional flanking and cross fires, tambours may be constructed in front of doors or windows. (A *tambour* is a redan-shaped bullet-proof stockade.) To remove the dead angle at the base of the wall, a machicoulis may be constructed. (A *machicoulis* is a bullet-proof shield which projects beyond the face of the wall, and allows vertical fire to be delivered between it and the wall.) A balcony may be transformed into an excellent machicoulis by making the railing bullet-proof, with beams or sand-bags, and cutting loopholes in the floor close to the walls of the building; a bullet-proof shield supported on skids in front of a second-story window serves the same purpose. To avoid danger of fire, combustible materials are removed from the building, the floors are covered with earth, and casks of water with buckets are placed in each room.

The exit from the building is on its unexposed side, and is covered by a bullet-proof door or tambour, as a protection against surprise. A shelter-trench may be constructed around the building to give an additional tier of fire; this trench is essential, if the walls are so thick that loopholes can be made only in the shields which protect the openings. The foreground is cleared to the accurate range of infantry fire, and is, if time permits, covered with obstacles. The retreat of the troops from an isolated building is secured by other troops in shelter-trenches in its rear, who sweep the ground on either side and in the rear of the building. In the defense of blocks of buildings, retreat is provided for the garrison, by making doorways through the partition walls; to check the pursuit, some of the partitions may be loopholed.

In European wars, isolated buildings and groups of

buildings have always been important tactical features of a battle-field, as the buildings and inclosure walls are usually of strong masonry. The Farm of St. Hubert [Pl. XVI], which played an important part in the battle of St. Privat-Gravelotte, is a two-storied masonry house which, with its outbuildings, faces the main road from Gravelotte to Metz. It stands in the corner of a courtyard, 75 yards square, which is surrounded by a high masonry wall. Abutting on the wall of the courtyard is a triangular garden, surrounded by a breast-high wall. The ground about the inclosure is open and unobstructed for a distance of 420 yards. This advanced post was garrisoned by one battalion and was only captured after a desperate assault made by four battalions supported by numerous batteries.

Villages.—In European wars, villages, which consist of an aggregation of strong masonry buildings, each surrounded by a strong masonry wall, have usually been important supporting or key points of battle-fields.

In organizing a village for defense, the first line is established behind the outer inclosure walls and hedges, and all streets leading into the village are closed by barricades. A second line of defense is established, by putting in a state of defense the houses and gardens of some parallel street, or other opening; exit from the village is covered by intrenchments in the rear. The artillery is placed in rear of the flanks where it can sweep the approaches and prevent an enveloping attack. Communications are made by openings in the walls which separate the adjacent fields or gardens. As the garrison of a village is intended only for passive defense, obstacles are freely used.

Plates XV and XVI show the villages and farms of the battle-field of St. Privat-Gravelotte, prepared for defense by the French army. The village of St. Privat was the supporting point, and St. Marie-aux-Chênes the detached post, of the VIth Corps; the village of Amanvillers the sup-

porting point of the IVth Corps; the farms of Montigny, Leipsic, and Moscow the supporting points, and the farms of Champenois, Chantrenne, and St. Hubert the detached or advanced posts, of the IIIrd Corps; and the village of Rozerieulles the supporting point of the left flank of the French army.

The village of St. Privat [Pl. XV], on the right flank of the French position at St. Privat-Gravelotte, is a small village of about one hundred masonry buildings with masonry inclosure walls; its south front is about one-third of a mile long. Three brigades of the Prussian Guard Corps from St. Marie-aux-Chênes attempted to capture this village by an assault over open ground about 3,000 yards deep, without a previous bombardment of the village by artillery. The assault was checked 500 yards from the village with heavy loss, and the village was captured only on being attacked in front and flank by the Prussian Guard and the XIIth Corps, after the fire of 120 guns had been concentrated on it. The heavy artillery fire of the Germans not only silenced the French batteries, but almost destroyed the village.

Even with artillery, it is sometimes difficult to drive a garrison from a village surrounded by masonry inclosure walls which it has had time to prepare for defense. In the investment of Paris, the little village of Bourget [Pl. XVII], built along a single road and intersecting stream, lay about two miles from Forts Est and Aubervilliers, two of the main forts of Paris, and about a mile in front of the outpost line of defense at Courneuve. It was captured from the Germans by the French on the 29th of October, 1870, and while occupied by three and one-half battalions with five field-guns, was for several hours exposed to a fire of thirty field and siege-guns at a range of about 1½ miles; by this fire the garrison lost but three men. It was afterwards recaptured with difficulty by nine battalions, assisted by two field and six horse-batteries. It was then put in a state of defense by the Prussian

engineers, and was held despite the fact that it was exposed to the fire of the heavy artillery of the defenses of Paris.

On December 21, 1870, the French attempted to retake this place with three brigades; the attempt was unsuccessful, although at first the place was held by five companies, which were only gradually increased by reinforcements to fifteen. The attack was prepared by the heavy artillery of the detached forts, field-batteries, and a few guns behind iron shields on railway carriages.

In their defense of the village of Bourget, the German engineers constructed three lines of defense as shown in Pl. XVII. The fortification work done in this village consisted in preparing the foreground by blowing up the railway station as well as isolated houses in front of the village; in tearing up as far as possible the railway leading towards Paris; in destroying some of the houses and walls in the interior of the village, which did not conform to the plan of defense; in constructing barricades of strong profile, bomb-proofs, abatis, shelter-trenches with traverses, military pits, wire entanglements, and covered communications.

In this country neither the isolated buildings nor the villages which were found upon the battle-fields of the Civil War were of a character admitting defense.

In the Spanish-American war in Cuba, the village of Caney was placed in a state of defense by surrounding it with six blockhouses, four of which were of wood, and two of stone; these were constructed on the circumference of a circle whose diameter was about one-third of a mile. Between the blockhouses were trenches for infantry. In the village itself a masonry church was organized for defense as a keep. The ground about the village within a range of several hundred yards was generally open, and commanded by that upon which the village was built. The Spanish garrison was said to have numbered 520 men, without artillery.

This position was attacked, 7 A.M. July 1, 1898, by an infantry division consisting of nine regiments, strength about 5,500 men, aided by four guns. It was only taken at 4.30 P.M., after the division was reinforced by a brigade of two regiments, bringing its strength to about 6,500 men. The loss of the assailants, in killed and wounded, was 444 men.

Cities.—When a town or city of considerable extent becomes an important position in any campaign or war, so that its possession is of material consequence to each belligerent, it is usually organized for defense, and protected from bombardment, by constructing a line of fortifications around the city proper and several miles from it. Washington, our capital, was thus fortified in the Civil War.

The defenses of Washington formed "a connected system of fortification by which every prominent point, at intervals of 800 to 1,000 yards, was occupied by an inclosed field fort; every important approach or depression of ground, unseen from the forts, was swept by a battery for field-guns; and the whole connected by rifle-trenches which were in fact lines of infantry parapet, furnishing emplacements for two ranks of men and affording covered communication along the line. Roads were opened wherever necessary, so that troops and artillery could be moved rapidly from one point to another, or under cover from point to point along the line. The woods which prevailed along many parts of the line were cleared for a mile or two in front of the works, the counterscarps of which were surrounded by abatis. Bomb-proofs were provided in nearly all the forts. . . . All commanding points, on which an enemy would be likely to concentrate artillery to overpower that of one or more of the forts, were subjected to the fire (direct and cross) not only of many points along the line, but also from heavy rifled guns from distant points unattainable by the enemy's field-guns." *

* "Defenses of Washington." Major-General J. G. Barnard, Colonel of Engineers, U. S. Army.

At the close of the war, the defenses of Washington [Plate XIV] consisted of sixty-eight forts and batteries, and three blockhouses, which entirely surrounded the cities of Washington and Alexandria. The individual works were bastion forts planned for an average garrison of five hundred men and sixteen guns. In order to conform to the topography of the site, which was intersected by the Potomac River, the Eastern Branch, and several small tributaries running in deep valleys, the works were divided into groups or sectors, each capable of an independent defense. The works in each group were so near each other that they could be mutually supporting with infantry or artillery fire. In the more exposed sector, south of the Potomac, there was a second line of works which formed bridge-heads covering the Long and Aqueduct bridges over the Potomac River.

The same general plan of fortification was followed by the Union engineers in the defense of the bases at Louisville and Covington, Ky., Memphis, Tenn., City Point, Va., Newberne, N. C., the depots of supply at Bowling Green, Ky., Knoxville, Murfreesboro, and Chattanooga, Tenn., and in the lines of investment in front of Petersburg, Va. In these lines the works were simple redouts usually of a square, pentagonal, or hexagonal form.

In the Confederate works at Donelson, Ky., Vicksburg and Port Hudson, Miss., Selma and Montgomery, Ala., Atlanta, Ga., Richmond, Va., and in the Union works about Nashville, Tenn., and Harrison's Landing, Va., the fortifications were continuous lines of uniform strength; the batteries were distributed along the lines in redans or lunettes, generally open at the gorge.

The lines of fortification constructed around Dresden by the Prussians, and those about Vienna constructed by the Austrians, in 1866, as well as the Turkish works about Plevna, were all similar to the lines about Washington. The Dresden redouts were large closed lunettes with ditch defenses and bomb-proofs, constructed for a garrison of

three hundred and fifty men and an artillery armament of sixteen guns. The Vienna redouts were similar, but had a garrison of three hundred men and an artillery armament of five guns. The principal Turkish works at Plevna were square redouts, without ditch defenses, 75 yards on a side; the Grivitza redout when captured had four guns, but many of the works had no artillery armament. The only specially novel feature in the works about Plevna was the second tier of fire, secured by a modification of the profile as shown in Fig. 9, Pl. II.

It will be seen from the above that the tendency of military engineers is to decrease the size of the redouts and also their artillery armament. The former is due to the greater efficiency of the infantry arm, which makes the fire of a small force with breech-loading rifles as efficient as that of a much larger one with muzzle-loading weapons. The latter is due to the greater efficiency of the artillery attack, which makes it desirable to scatter the guns of the defense in small batteries along the line, instead of concentrating them in a few redouts, where they would be soon silenced by the overwhelming concentrated fire of the attack.

It is generally considered advisable to construct the redouts wholly for infantry defense, whenever the topography of the site allows the artillery to be placed in secure positions, a few hundred yards in the rear of the redouts, from which it commands the intervals and approaches to the works. Gun-pits or epaulments are constructed for the artillery, but many of the field-guns are kept in reserve, and only moved into position when the enemy discloses his point of attack. The profiles of the works and the bomb-proofs are made strong enough to protect the garrisons from the direct and vertical fire of siege-artillery. The redouts are surrounded by a belt of obstacles, of which the high entanglement is perhaps the most difficult to destroy or to pass; in wooded sites abatis are ordinarily constructed.

The garrison of the defenses of Washington was estimated as 25,000 infantry, 9,000 artillery, and 3,000 cavalry, making a total of 37,000 to defend a line 36 miles long. This was based on two rifles per yard for each front face, and one per yard on each rear face of the forts and trenches, and three reliefs of cannoneers for each gun. The cavalry were to be employed in outpost duty watching the different roads leading to the city. On account of the supreme importance of the capital, a covering army of 25,000 men was deemed essential whenever the enemy should appear within striking distance of it. The total defending force was therefore estimated at 1879 men per mile. The Turkish army in Plevna during the investment numbered 1875 men per mile of perimeter of defense. If the garrison is weak, the intervals between the works may be converted into a strong obstacle, as at Covington, Ky., where the defensive line was partially formed of wide slashings. Ordinarily the intervals between redouts are occupied by one or more lines of shelter-trenches with emplacements for artillery. The development of these trenches is now very great, since the reserves, as well as the firing line, must be kept under cover; at Plevna the Turkish line of defense was 24 miles, and the shelter-trenches 35 miles long.

Woods.—A grove of moderate extent, the approaches to which can be swept by artillery fire, makes a very strong supporting point, when properly prepared for defense. It conceals the supports and reserves, and partially protects them from the assailant's fire. The line of defense is fixed along the edge of the woods, where the defenders are covered by breast-works of logs, brush, and earth, and are further protected by an abatis constructed of the trees felled in clearing the foreground. In the rear of the line, there is a belt cleared of all undergrowth, so that the line of defense may be properly controlled by its officers. Since the edge of the grove is a conspicuous target for artillery, it is sometimes better, if time permits, to intrench the firing

line fifty or more yards in advance of the wood, and keep the latter for the reserves.

If the grove is large it is divided into sectors, and each is assigned to some complete unit; it is advisable to separate the sectors by slashings, so that the success which the assailant may attain in one sector will not imperil the safety of the defenders in the adjacent sectors. If the edge of the wood is not composed of salients and re-entrants, flanking fire is secured by the construction of redans along its front. Roads leading into the wood are barricaded at, or in front of, the firing line; in the interior, trees bordering upon the roads are partially cut through, so that they may be readily felled to close the roads in case of necessity. Roads for communication between the firing line, supports, and reserves, are opened and plainly marked by signs.

If the line of defense passes through a wood of considerable extent, it is necessary to throw up a practically continuous line of intrenchment. Because of the ease with which the assailant can conceal the troops which he may concentrate for an assault, and because of the difficulty of quickly reinforcing every part of the line, it is advisable to have a second intrenched line of defense, behind which the troops can rally if the first is pierced. In woods, the assailable parts of the line are the flanks; they are therefore protected by impassable natural obstacles, as swamps, rivers, etc., by heavy slashings, or by strongly intrenched lines. The artillery, which has a limited front field of fire, is, if possible, placed so as to have flanking fire in front of the different parts of the line.

Defiles.—A defile is any portion of a route, followed by a body of troops, over which the troops are compelled to move in column, and cannot deploy into line of battle to receive a front attack. A bridge over an unfordable river, a ford, a causeway over a marsh, a deep valley, and a mountain pass, are the defiles which are ordinarily encountered in military movements. Since an army

marches on as broad a front as possible, with its various columns on parallel roads, when a defile is encountered there is delay in the movement, due to the concentration of the army, and its passage in a single column. If the army is moving in retreat before a pursuing enemy, this delay may be fatal unless proper precautions have been made for it in advance. To prevent disaster in case of defeat, the important defiles in rear of an army, such as important bridges and mountain passes, are usually fortified and garrisoned. It is sometimes equally important to hold the defiles beyond the flanks of the army, to check any movements the enemy may make to turn the flanks by passing through these defiles.

Bridge-heads.—The line of fortifications, constructed for the protection of any defile at a river crossing, is called a bridge-head. If the works are at both ends of the defile, it is a *double* bridge-head; if at only one end, it is a *single* bridge-head. When the works are intended to cover the passage of a large army, the bridge-head is fortified in a manner similar to that of a city, by the construction of a line of redouts at a distance of two or more miles from the bridges, so as to give a considerable area within which the army may camp while its units are crossing the river. An inner line is also constructed close to the defile to cover the retreat of the rear guard. The fortifications of Washington, D. C., Covington and Louisville, Ky., Nashville, Tenn., and many other of the important fortifications of the Civil War, were bridge-heads. When the main object of the bridge-head is to prevent the use or obstruction of the defile by small raiding parties, a much simpler construction suffices; such a bridge-head consists of a redout or blockhouse at one or both ends of the defile, to shelter the garrisons assigned to its defense. Pl. XVIII shows the plan of some of the simple bridge-heads employed in the defense of the bridges over rivers, in the central states, during the Civil War. The defense of a mountain pass or

a valley differs from that of a river crossing, in the precautions taken to prevent the enemy from securing a lodgment on the heights overlooking the pass. For this purpose all side trails are intrenched as separate posts. In long passes or valleys secondary positions are intrenched within the pass.

CHAPTER IX.

TACTICAL EMPLOYMENT OF FIELD FORTIFICATION.

As stated in Chapter I, strategy determines the location of the battle-field, tactics regulates the employment of the troops upon the field, and fortification so modifies the natural features of the site as to increase the chances of success.

Tactics recognizes two kinds of action, offensive and defensive, and it divides defensive actions into passive and active. *Offensive action* has for its object the defeat and destruction of the opposing force without compromising the safety of the army; it is tactically successful when the opposing force is driven from the field of battle or is captured upon it. *Passive defense* has for its object the holding of a position until it has ceased to be of further military value; it is tactically successful when the assailant has been compelled to abandon his attack, or has been obliged to resort to a blockade or to a siege. In the ordinary battle, one of the opponents, because of his weakness, selects and occupies a position upon which he awaits the attack of his adversary; the action of one side is purely defensive, and of the other purely offensive. Occasionally one of the adversaries may await the attack of his opponent, who is only slightly superior, and hold in reserve a large body of troops with which to act offensively as soon as a favorable opportunity presents itself; this is known as *active defense*. Its aims are the same as the purely offensive action, to defeat and destroy the assailant; it is tactically successful only when the assailant is

compelled to retreat or to surrender, on account of losses inflicted by the counter-attack.

Passive Defense.—The following features of a position are considered tactically favorable to the troops making a passive defense:

(1) Its extent is proportioned to the number of troops available for the defense.

(2) There are strong points upon which to rest the flanks so that they cannot be turned.

(3) Its lines of retreat are ample and secure.

(4) The line of defense is so located as to overlook the ground over which the assailant must advance, and sweeps with its fire all the lines of approach.

(5) Its topographical features conceal the defender and shelter him from the fire of the assailant, without interfering with the fire of the defense.

(6) The ground in front impedes the movements of the assailant.

(7) The communications in the rear are ample for the rapid movement of the supports and reserves.

If the commander of the army on the defense can find a position which, besides fulfilling all the strategical requirements of the campaign, fulfils the above conditions, and there is sufficient time to give it careful study, its organization for defense is generally made in the following manner. After deducting the reserve, the entire line is divided among the corps or infantry divisions, duly considering the strength of each unit and the natural strength and importance of each part of the line; each unit is charged with the defense of a definite length of front. Along the front of every corps or division there will probably be some hill, grove, or inclosure which, on account of the view, the field of fire, or the protection that it gives the defender, becomes a key-point of that portion of the line. These points are at once occupied by troops who convert them into strong positions of defense by utilizing the art of fortification; they then become the *supporting points* of the position.

In organizing a supporting point, the first step is to clear the foreground to a distance of at least 400 to 600 yards. Simple trenches are then constructed to protect the troops assigned to the defense; these are generally strengthened until the parapets can resist field-artillery shrapnel, and deep trenches or covered shelters protect the men from shrapnel fire. Obstacles may be constructed in front of these positions when practicable, as the troops assigned to their defense are not intended to make any counter-attack. The ordinary form of supporting point for the front of an infantry division is a group of works defended by about 800 rifles; in our service the garrison would be two battalions or one regiment. A grove, village, or inclosure defended by a similar garrison may be utilized to replace the earth intrenchments. Pl. IX, Fig. 69, shows a group of works proposed by the French engineers for this purpose; a field redout as shown in Pl. IX, Fig. 70, makes a strong center for such a group of works. Secondary key-points may be strengthened by half-closed or closed works like those in Plate VIII. The distance between the centers of the principal points does not exceed 1½ miles; between secondary points the distance is about 800 to 1,500 yards. Supporting points are also valuable in the rear of the flanks, if these do not rest on impassable obstacles.

If the ground between the supporting points is generally open, it may be weakly occupied, and the main body kept in reserve, until the direction of the attack is developed. The troops in the intervals between the supporting points are covered by straight trenches, having such directions that strong front fire can be brought on the foreground, and that cross fires may be delivered in front of the supporting points. If no forward movement over the trenches is contemplated and time permits, their profile may be that of the standing or complete trench; if a counter-attack is proposed, they should be kneeling

trenches with intervals between them for the movement of artillery.

The artillery is posted in the intervals, preferably a few hundred yards behind the infantry, where it can assist in the defense both of the supporting points and the intervals; it may be sheltered in gun-pits or behind epaulments.

The character of the works of defense is concealed from the assailant by adapting the works to the site, so that command over the exterior is given by the natural elevation of the ground and not by raised parapets. Parapets which might attract attention are covered with sods, weeds, etc., as heretofore described. If the ground in front of an interval is covered with woods, more troops are detailed for its defense, and the intrenchments are made of stronger profile and are strengthened by obstacles. If the position is along the crest of a height, the infantry trenches are preferably just in front of the military crest so as to leave the plateau for the disposition of the artillery. [The *military crest* is the most elevated crest from which all the foreground is visible. It is usually in front of and lower than the main crest, Pl. IX, Fig. 68.] Instead of following the irregularities of the crest, it is frequently better to place the company or battalion trenches in echelon, so as to sweep the foreground without exposing the defenders to enfilade fire. Steep slopes are defended by several tiers of shelter-trenches and by flanking fires.

The positions assigned in the drill regulations to the supports and reserves of the firing line will ordinarily expose them to the enemy's fire; they are therefore protected by covering trenches. The second line and the general reserves are usually sheltered by the natural features of the site, but may also be compelled to con-

ct shelters if exposed to the enemy's artillery.

is usually considered advisable to occupy any posi-

in advance of the line which are of small extent,

admit of vigorous defense, and are within supporting distance of the main line. These are called *advanced posts* and are organized by the construction of simple trenches, or by converting a grove, a house, or an inclosure into a defensive position. Positions on the line of retreat may be similarly organized, or organized in the manner of supporting points. If detached posts are occupied, they are intrenched in a similar manner. [A *detached post* is one beyond supporting distance from the main line.]

The improvement of the communications is undertaken by the engineers attached to the reserves. Roads are opened and repaired, bridges are repaired and constructed, and signs put up indicating the direction to be taken to reinforce any part of the line. At night lanterns are hung to indicate the lines of approach from the reserves to the firing line.

If an unexpected battle is fought, as in an unforeseen encounter of the armies, the same general principles are observed. The advance guard occupies one or more natural supporting points, and thus covers the deployment of the army. Each division and corps intrenches itself as it arrives on the field; and when the army is in position, the errors made in this hasty intrenchment are corrected.

It is, however, very rare that a site can be found which fulfils all the requirements of a good position. Field fortification must, therefore, be resorted to, to neutralize the defects of one which does not possess all the desirable features.

First Feature.—A purely passive defense indicates an inferiority in numbers, discipline, or leadership; a position is occupied to check, temporarily or permanently, the advance of the assailant along some line of operation. In such an action it is essential that the defender secure himself against flank attacks and protect his lines of retreat. These conditions may compel him to take up a position whose extent necessitates his occupying the whole, or a part, with a weak line of troops; field fortification

enables him to do this within limits, by increasing the fire action of the defense and decreasing that of the attack. Military authorities usually state that, under ordinary conditions, the front of defense, when measured in yards, should not exceed from one-fifth to one-eighth the numerical strength of the army.

It is difficult to say to what extent field fortification, skilfully employed, can replace numbers. In the Virginia Campaign of our Civil War, in 1864 and 1865, the Confederate army about Richmond and Petersburg under General Lee, numbering about 57,000 men, was able to prolong its flanks, and to resist all front attacks of the Union army under General Grant, numbering 125,000 men, until its lines were extended to a length of thirty-seven miles. The Confederate position had the advantage of interior lines with good communications, while the force of General Grant occupied exterior lines which were intersected by two wide, unfordable rivers, the James and the Appomattox. In this campaign both armies were composed of seasoned troops, and the positions were gradually strengthened during an occupation of several months.

In the Franco-Prussian War General Werder, on the Lisaine River, was able to hold a line twenty-eight miles long with a force of 45,000 men, against the attacks of an army of nearly three times its strength which was moving to the relief of Belfort. This position was selected on the 10th of January, 1871, and was occupied and strengthened by the retreating German army during the following days. It was repeatedly attacked during the 15th, 16th, and 17th of January, but all attacks were repulsed, until a relieving force compelled the French to retire. In these operations the French army was composed of hastily organized corps of raw troops.

In the Russo-Turkish War the army of Osman Pasha, of about 35,000 to 40,000 men, held the position of Plevna against a Russian force of over 100,000 men until compelled by starvation to surrender. This position was also gradu-

ally strengthened during an occupation of several months.

Second Feature.—The weak points of any defensive line are the flanks; these must be secured by resting them upon some natural obstacle, as a river or marsh, or, if this be impossible, by strengthening them by field fortifications. The latter may be redouts, half-closed works, or lines of intrenchments in echelon, if the flanks are in open country; or they may be intrenched lines protected by such obstacles as slashings and abatis, if the flanks rest in a wood. Failure to secure the flanks properly has resulted in innumerable defeats, among which may be cited the battle of Chancellorsville in our Civil War; in this battle the Union army, temporarily on the defensive, was defeated and compelled to retreat, on account of an attack made upon its right flank, which was left unprotected in a thick wood. The defeated army numbered 124,000 men, while the entire opposing force numbered only 62,000 men, and the force making the flank attack numbered only 26,000. The battle of St. Privat-Gravelotte, in the Franco-Prussian War, was also lost because the right flank of the French position was exposed to a flank attack without being protected by intrenchments; the left flank, which rested on a river and was intrenched, easily repulsed attacks made by two and three times the number of the defenders.

Third Feature.—The retreat of a defeated and usually a more or less demoralized army is a very delicate operation. In order to gather the scattered units and conduct them to the highways, it is necessary to check, temporarily, the assailant's pursuit; this can best be accomplished by intrenched posts on all the principal lines of retreat. These will give time for the rallying of the troops and the organization of a rear-guard to cover the retreat. If the line of retreat be in rear of one of the flanks of a position, the strongest posts must be in rear of that flank.

Fourth Feature.—To overlook the ground in the imme-

diate front, the line of defense must be established along the military crest of the site. The trace of this crest is ordinarily an irregular line made up of salient and reëntrant angles; the salients are naturally weak, on account of their sectors without fire, while the reëntrants are naturally strong, because of their cross fires. The salients are therefore the points which must be artificially strengthened by intrenchments and obstacles. The approaches can be thoroughly swept by front and cross fires when the foreground has no obstructions or dead spaces; in general this can only be secured by clearing the foreground as explained in Chapter IV.

The effect of an unfavorable foreground was well illustrated in the battle of Chattanooga in our Civil War, in the attack on Missionary Ridge by the Army of the Cumberland. This ridge rises about four hundred feet above the plain of Chattanooga, and its slope is about six hundred yards in width; the slope is steep, rough, and at the time of the battle was wooded; it could not be thoroughly swept, even at close range, by infantry or artillery fire. The left wing of the Confederate army under General Bragg, numbering 10,000 to 12,000 men with 48 guns, occupied about three miles of the ridge. The main body was intrenched along the crest, and intrenched outposts were placed on the slope and at its foot. The Army of the Cumberland, in front of this line, numbered about 22,000 infantry, and was posted in trenches about one mile from the crest of the ridge. The space between the Union line and the base of the slope was an open plain. At three o'clock P.M. November 25, 1863, the Army of the Cumberland was ordered to seize the trenches at the foot of the slope, and advanced to the attack in two lines of battle with advanced skirmishers. The outposts at the foot of the slope were driven back or captured, and the Union soldiers, seeing that the character of the foreground concealed them from the Confederate line, without further orders advanced slope and captured the crest. The total loss suf-

fered by the Army of the Cumberland in this assault, without artillery assistance, and in the pursuit which followed it, was 2,800 men. At the northern end of this same ridge, General Sherman had at his command 23,000 men, and was vainly attempting to dislodge General Hardee, who had 13,000 men; the latter, however, occupied a line only a mile and a half long, with well protected flanks and a foreground well swept by front and cross fires.

Fifth Feature.—Occasionally a sunken road or a stone wall is one of the accidental features of a battle-field which may be utilized by the defenders to secure cover. At the battle of Fredericksburg, Va., some of the Confederate troops, sheltered by a stone wall and sunken road, repulsed several assaults and caused the retreat of the Union army. As a rule, however, all cover upon the field of battle must be earth shelters artificially constructed, as few accidental shelters will be found to have the proper direction for the firing line. The reserves are ordinarily protected by the inequalities of the ground, but if such cover is not available they too must construct artificial covering trenches.

Sixth Feature.—Very few natural obstructions will give the defenders an unobstructed field of fire, which is the most important feature of a defensive position. As a rule, if obstacles are deemed essential, it will be necessary to remove the natural, and replace them by some of the artificial ones described in Chapter IV.

Seventh Feature.—Easy communication in rear of a position, for the movement of supports and reserves, is essential to a vigorous defense. The great disadvantage of passive defense lies in the fact that it allows the assailant to select his point of attack; and the defender must therefore be ready to meet an assault at every point in his line. This makes it essential that supports and reserves move to the point of attack over the shortest routes in the shortest possible time. If the position is an extended one, and especially if broken up by ravines and woods, the

engineers must at once open new roads and construct bridges, so that the movement of all troops in rear of the fighting line may be accelerated, both parallel and perpendicular to that line.

Active Defense.—An active defense by an army inferior or about equal to the opposing army can only be made by the aid of field fortification. The entire front of the position may be divided into zones, the passive and the active. The passive zone is strongly intrenched and covered by obstacles so as to retard, as long as possible, the advance of the troops in its front; the troops along this part of the line are reduced to a minimum of one or two to the yard with a strong reserve. The active zone is either unprotected or lightly intrenched without the use of obstacles; in its rear are concentrated all the available troops for making the counter-attack at the proper moment. The attack made by General Lee on the army of General McClellan at Mechanicsville and Gaines' Mill is a good example of an active defense. The Union army, which was on the offensive, numbered 105,000 men, and was divided into five corps. The front of the position from White Oak Swamp to Mechanicsville was intersected by the Chickahominy River, leaving one corps, the Vth, north of that river, and the other three of the front line to the south; the reserve was also south of the river. The Confederate army, numbering about 70,000 men, was south of the Chickahominy, occupying an intrenched line in front of the main body of McClellan's army, and awaiting a reinforcement of 20,000 men. General Lee planned a counter-attack which was to be made as soon as his reinforcements arrived. In his main line south of the Chickahominy he proposed to leave 30,000 men well intrenched, to check any advance of the 75,000 who lay in their front, while he concentrated north of the Chickahominy a force of 60,000 to crush the Vth Corps, which only numbered 30,000 men. If this attack ould be successful, it would at once place him in con- f General McClellan's communications which led to

White House, north of the Chickahominy, and might lead to the destruction of the Union army. The attack was made as planned, and while not destroying the Union army, it caused it to retreat to the James River, and led to its final withdrawal to another part of the theater of war and the abandonment of the Peninsula as the theater of operations.

Offense.—Field fortifications are not as extensively employed by the assailant as by the defender. They may, however, be advantageously employed in guarding the passive part of a line from counter-attack, whenever the attack is made by one flank or by the center; in organizing for defense any advanced or detached post captured from the enemy; in sheltering the advanced skirmish line when it has reached a position from which it cannot advance further without reinforcements; and in organizing positions to cover the withdrawal of the attacking forces, should the attack fail. In the battle of St. Privat-Gravelotte, to cover a possible repulse, the Germans at once organized the villages along their line and also the detached post of St. Marie-aux-Chênes, and the advanced posts of Chantrenne, Champenois, and St. Hubert, as soon as they were captured from the French. In Skoboleff's attack on the redouts south of Plevna, he found that the only way he could make any progress was to intrench his skirmish lines, as soon as they were brought to a standstill by the fire of the defense. This prevented their retreat and made a cover under which another line could be advanced to gain a little more ground. In the Russian attack on the great redout Gorni-Dubniak, near Plevna, although there were 16,000 men and 54 guns in the attack and only 4,000 men with 4 guns in the defense, the attack would have failed, had the assailants not found shelter in a ravine two hundred yards from the work. In this they remained until dark and then made a successful night attack.

CHAPTER X.

STRATEGICAL EMPLOYMENT OF FIELD FORTIFICATION.

Deliberate intrenchments are designed and constructed for the purpose of enabling a weak garrison to hold an important position against a strong attacking force. It is an axiom in war that real success results only from offensive movements; bases, lines of communication, etc., should, therefore, be weakly garrisoned to withdraw as little strength as possible from the active field army.

Bases of Operations.—If the base of supplies is a contracted area, as in invasions by sea, it should be absolutely secure against capture by the ordinary operations of a field army, so as to cover the embarkation of the army in case of disaster. The most famous of such bases was that protected by the lines of Torres Vedras, constructed by direction of the Duke of Wellington in 1809–10 during the Peninsular War. In 1810 Napoleon, being at peace with the rest of Europe, decided to make a determined effort to drive the British out of Spain and Portugal, where they were organizing and assisting the struggle of these states against the Imperial power. The principal allied army, composed of 30,000 British troops assisted by as many Portuguese, was commanded by Wellington, and posted on the frontiers of Portugal to protect that country from invasion along the roads from Salamanca and Seville, via the frontier fortresses of Ciudad Rodrigo and Almeida on the north, and Badajos and Elvas on the south. The base of the army was the peninsula between the Tagus River and the Atlantic Ocean upon which is situated the capital,

Lisbon. To cover his retreat in case of defeat, he intrenched his base by constructing two parallel lines of fortification across the peninsula in the vicinity of the village of Torres Vedras. Each line was twenty-five miles long, and was composed of numerous redouts, armed with artillery, and connected by shelter-trenches and obstacles. The approaches to each line were obstructed by mining the roads, by destroying the bridges, by flooding the valleys, and by scarping the hillsides. On the sea-coast, about thirty-five miles in the rear, were inner lines covering the point of embarkation.

The northern French army, strength about 70,000, under Massena, was operating on the line from Salamanca; it was composed of the corps of Ney, Junot, and Reynier, with the cavalry corps of Montbrun. The southern army, strength about 60,000, under Soult, was composed of the corps of Victor, Mortier, and Sebastiani; it was operating on the line from Seville, conquering Granada, and besieging Cadiz. Massena took Ciudad Rodrigo in June, Almeida in August, and proceeded against Wellington, who, after the battle of Busaco, fell back behind the lines of Torres Vedras. Massena reached this position about the 10th of October and was surprised to find it fortified. After a careful reconnaissance, he decided that an attack on the lines gave little hope of success; he therefore withdrew to the vicinity of Santarem to await reinforcements or a British attack. For five months he remained here, while his communications were being harassed by Spanish guerrillas; at last he was compelled to retreat with an army demoralized by failure, inaction, and starvation. Soult was so busy in pacifying the South that he only appeared at Badajos as Massena was retreating. This period marked the turning point of the Peninsular War; Wellington was not again compelled to take refuge in these lines, which had probably saved his army.

If the base is an unfordable river, provision must be made for the constant, free, and secure movement of the army

and its supplies across the river. This is effected by the construction of bridge-heads to cover the important points of crossing. In the Civil War, the Potomac and Ohio rivers formed the base of the operations of the Northern armies, and bridge-heads were constructed at Washington, Cincinnati, Louisville, Smithland, and Paducah, where the principal railways and rivers penetrating the South intersected the base. For a similar reason, the passes are fortified if the base is a range of mountains.

Depots of Supplies.—Depots of supplies, which are secure against raiding parties, and which can be held temporarily even if the army is separated from them for a short time, are essential to the progress of any campaign. A few of the most important depots may be fortified in time of peace, but most of them can only be organized after hostilities have begun, and the theater of operations of each army becomes definitely settled. In the Civil War, the depots of supplies for the Union armies in the East were Washington, Fort Monroe, City Point, and the cities along the seaboard and great rivers; in the West they were the principal cities on the great rivers and railways which fell into the hands of the Union armies as they advanced;—New Orleans, Vicksburg, Memphis, Nashville, Chattanooga, etc. Each was strongly fortified and became a small base for the military operations in the vicinity. A failure to protect such a depot of supplies may cause the failure of a campaign. When, in the fall of 1862, General Grant began an overland campaign against Vicksburg, he established his depot of supplies at Holly Springs, Miss., on the Mississippi Central Railway. After he had advanced well along this railway, the Confederate General Van Dorn captured this depot and destroyed all the supplies gathered for the campaign. This compelled General Grant to retreat and abandon his overland campaign.

Communications.—A modern army must depend upon the railways and waterways of a country for supply. Since the movement of troops and supplies over them is practi-

cally continuous, when an army invades a hostile country, all railways used as lines of supply must be protected from raids by hostile citizens, as well as from those made by the hostile army. The weak points of a railway system are its tunnels and bridges, which are the parts most easily destroyed and the most difficult to repair; these are usually guarded by small detachments of troops, sheltered in blockhouses or field-works.

General Sherman says of the defensive system of the Atlanta-Chattanooga Railroad organized in his campaign against Atlanta: "We had strong railroad guards at Marietta, Kenesaw, Altoona, Etowah Bridge, Kingston, Rome, Resaca, Dalton, Ringgold, and Chattanooga. All the important bridges were likewise protected by good blockhouses, admirably constructed and capable of a strong defense against cavalry or infantry; and at nearly all the regular stations we had small detachments intrenched."

If the line of retreat of an army crosses an unfordable river, or traverses a mountain pass, these points are secured to the army by the construction of fortifications known as bridge-heads at the former, and by redouts or blockhouses in the latter defiles. A weak bridge-head at Mill Springs on the Cumberland River saved the Confederate army under General Crittenden from capture after its defeat at Logan's Cross Roads, January 19, 1862. The only means of crossing the river was a single ferry-boat. The bridge-head at Washington no doubt prevented an active pursuit of the Union army after the first and second defeats at Bull Run. The capture of Napoleon's bridge over the Beresina by the Russians almost led to the destruction of his army, in the retreat from Moscow.

Objectives.—If there be any important city, the possession of which will naturally be the object of a campaign, it is usually protected by fortifications. The capital of a country is such a city, as its possession will give to the assailant a great moral, if not a material, advantage over the defender who has been unable to retain it. If not pro-

tected by permanent works, the capital is usually surrounded by field fortifications soon after the outbreak of the war. Both Washington and Richmond were thus fortified during the Civil War.

Strategical Points.—During the progress of a war, certain points in the theater of war will become of great importance, due to the direction or character of the military operations. They are usually located along the natural lines of invasion of a country, and, if strongly held, will always delay and may even defeat an offensive campaign. In our Civil War, the Confederates, at an early day, feared an advance upon Richmond from Fort Monroe as a base, along the York and James rivers and the peninsula between them. To obstruct such a movement, the Confederate engineers constructed a line of works across the peninsula, between Yorktown and Mulberry Island, following the course of the Warwick River. Yorktown was made a strong fortress, mounting sea-coast guns which commanded the York River; on Mulberry Island there was a small redout with guns commanding the James River; between the two the Warwick River, an insignificant stream, was dammed in various places so as to overflow the bottom lands and make it impassable; and along its rear was a line of redouts and batteries commanding the dams and every line of approach. About a year after the works were begun, General McClellan, unaware of their existence, began his Peninsular Campaign along the route thus guarded; with an army of over 50,000 men he came upon the Yorktown lines, April 5, 1862, when they were guarded by only 13,000 men. After making a careful examination, he decided that they were too strong to be taken by assault; he therefore sent for heavy artillery and began a regular siege. His movements were delayed by this siege for one month, which enabled the Confederate authorities to strengthen their works about Richmond and rally their forces to its defense. The lines of Yorktown no doubt contributed largely to the failure of the

Peninsular Campaign, as the delay not only strengthened the Confederate position, but weakened the confidence of the authorities in General McClellan, who had based his plan on surprising the Confederates, and was himself surprised. Fort Henry on the Tennessee and Fort Donelson on the Cumberland were constructed for a similar purpose, to check an invasion of the Northern armies along these navigable rivers. They failed in their purpose because they were not properly constructed and garrisoned. Vicksburg, Port Hudson, Columbus, and Island No. 10, on the Mississippi River, Nashville, Chattanooga, and Atlanta on the railway, and Mobile on the Gulf were other strategical points, in the theater of the Civil War.

Napoleon testifies, in his Commentaries, to the value of field fortification on an enemy's lines of operation. In his campaign of 1796–97 he was besieging an Austrian army which had taken refuge in the fortified town of Mantua, and at the same time was guarding the besieging force, against the attacks of the Austrian armies sent through the Tyrol to its relief. These armies came from Trent in the Tyrol, and usually passed down either along the west or the east side of Lake Garda. If they came down the west side of the lake, they were compelled to pass through the mountain defile of Rocca d'Anfo ; if down the east side, through the defile of Corona, a gorge of the Adige River, or along the plateau between the Adige and Lake Garda commanded by Rivoli and San Marco. He says: "I should have occupied the plateau of Rivoli, Corona, San Marco, and Rocca d'Anfo with good works of wood, or even masonry. The Adige carries rafts of wood from the Tyrol to Ferrara and Venice. Lime and stone are abundant. In six weeks there could have been established on the plateau of Rivoli, the Chapel of San Marco, at Corona, and Rocca d'Anfo, four forts, each armed with 15 cannon and 400 to 500 men, which would have placed these positions out of danger of surprise or assault; they would have been more valuable to the army than a reinforce-

ment of 15,000 men." A reinforcement of 15,000 men would have been equal to one-third his entire army.

Strategical points need not necessarily lie directly upon the enemy's line of operations, but may be some distance to one side of that line. The town of Plevna, which will be described hereafter, was such a point.

CHAPTER XI.

CAMPAIGNS ILLUSTRATING THE UTILITY OF FIELD FORTIFICATION.

Campaign in Virginia in 1864–65.—[Pl. XXVII.]—In the spring of 1864 the principal Union armies in Virginia consisted of the Army of the Potomac, under General Meade, strength 119,000 men, formed of the IInd, Vth, VIth, and IXth Corps, and the Cavalry Corps; and the Army of the James, under General Butler, strength 39,000, formed of the Xth and XVIIIth Corps and a cavalry brigade. The former was in camp north of the Rapidan about Culpeper, and the latter about Fortress Monroe on the peninsula between the York and James rivers. General Grant was in command of both armies, and directed a simultaneous movement on Richmond, in which the Army of the James was to be transferred by water to the mouth of the Appomattox River, and from thence to operate along the south bank of the James River. The opposing Confederate armies were the Army of Northern Virginia, under General Lee, strength 62,000, the army under General Beauregard, strength 23,000, and the troops in the defenses of Richmond, about 6,000. The Army of Northern Virginia occupied an intrenched line on the south bank of the Rapidan, between Mine Run and Orange Court House. The army under General Beauregard was being organized between Richmond and Petersburg from troops withdrawn from the Carolinas.

The campaign began on May 4, 1864, when the Army of the Potomac crossed the Rapidan, at Germanna and

Ely's fords, and penetrated the wooded country known as the Wilderness, thus turning the right flank of the Confederate position. The Confederate army at once moved eastward to intercept this movement, and on the 5th and 6th of May the armies fought the battle of the Wilderness, in which each army was formed parallel to the general line of operations. As united action was almost impossible, owing to the character of the country, the battle was a series of detached engagements, in the course of which each army intrenched its position to protect its troops from surprise.

On May 7th both armies were completely intrenched and separated by a distance varying from one-quarter to three-quarters of a mile. As the Confederate line was only five and one-half miles long and could easily be held by the available troops, General Grant decided not to risk any further assaults, but to move on to Spottsylvania and thus compel General Lee to retreat.

The movement was begun in the evening of May 7th; the IInd Corps was left in the trenches to protect the movement, while the others, preceded by cavalry, moved off on the principal roads towards Spottsylvania. The movement was, however, so delayed by the Confederate cavalry which had obstructed the roads by slashings, that on the morning of May 8th, when the advance guard reached Spottsylvania, it found a Confederate force which it could not dislodge intrenched across its path. As the remainder of the Confederate army arrived upon the field, it intrenched itself in prolongation of the original line until it finally occupied a great redan, 6 miles long, both flanks of which rested upon the Ny River, a marshy stream not easily crossed. The salient, which was recognized to be a weak point, was afterwards strengthened by a great pan-coupé, one mile to the rear, which was occupied by a reserve. The Union corps, arriving in succession, intrenched themselves on a parallel line, separated from the Confederate line by a distance varying from two hundred yards to

one-half mile. The positions about Spottsylvania were occupied between the 8th and 19th of May, during which time several assaults were made on different parts of the Confederate line by the Army of the Potomac, with no other marked success than the driving of the Confederate army back from the salient to the pan-coupé. The casualties suffered by the Army of the Potomac in the battles of the Wilderness and Spottsylvania, in killed, wounded, and missing were about 33,000 men, mostly due to front attacks on intrenched lines. Being unable to drive General Lee from his position, General Grant withdrew his army under cover of the Vth and IXth Corps, and moving eastward, changed his line of operations to the Fredericksburg Railway. When he arrived at the North Anna River, however, he again found General Lee intrenched across his front. The position was so strong that General Grant decided not to attack it, but to move down the Pamunkey and cross at Hanovertown. This was successfully accomplished, but on resuming the direct road to Richmond General Lee was found in his front, intrenched between the Chickahominy River and the Central Railroad, along Totopotomy Creek.

While these operations were being carried on by the Army of the Potomac, the Army of the James had been transferred to the junction of the James and Appomattox rivers, and there established bases at City Point, on the south bank of the James, and on Bermuda Hundred, the peninsula between the James and Appomattox. In the latter place, a strong line of intrenchments was thrown up between the two rivers. From this line, the Army of the James moved to attack Richmond from the south, but was defeated by General Beauregard in the vicinity of Drewry's Bluff, May 16th, and fell back to its intrenchments. It was here imprisoned by the Confederate army, which constructed a parallel line across the peninsula. As the Army of the James was unable to operate in its front, General Grant directed General Butler to send the XVIIIth Corps by water

to White House, on the Pamunkey River, to take part in the operations about Richmond. This gave General Grant an additional corps of 17,000 men, but was offset by reinforcements sent to General Lee by General Beauregard, about 15,000 men. General Grant sought a weak point in General Lee's new line of defense, and finally decided to assault the lines about Cold Harbor. Although made with his entire army, the assaults were all repulsed, and he was forced to continue his flank movement by crossing the James River. Under cover of its intrenchments, the Union army was withdrawn; the XVIIIth Corps was transferred by water from White House to Bermuda Hundred, and the other corps moved down the James River to Charles City C. H., where they crossed the river on the 15th and 16th of June, and moved on Petersburg. When the Union army first arrived in front of Petersburg the lines were not strongly held, as the movement was not anticipated by General Lee; the outer lines were, therefore, carried by assault, but no further progress could be made, as strong interior lines were soon constructed and a strong force was sent to hold them. The total casualties in the operations of the Army of the Potomac from May 4th until June 30th are given by General Humphreys, the Chief of Staff of that army, as 61,400 in killed, wounded, and missing; a force nearly equal to the original strength of the Confederate army. The general plan of operations now adopted by General Grant was to extend the original lines of Bermuda Hundred to the north of the James River as far as the Chickahominy, and south of the Appomattox River around Petersburg. This would compel General Lee to extend and weaken his lines, and would also threaten the railways extending south and west from Richmond and Petersburg, which were the lines of supply of the Confederate army. Siege operations were begun along the Petersburg front, and assaults were to be made wherever there seemed to be a probability of success. In accordance with this plan, assaults were made on the Confederate lines

north of the James River in August, September, and October; a mine was exploded and an assault made on the Petersburg front July 30th; and the Union lines were extended westward, so that at the close of 1864 they extended to Hatcher's Run west of the Wilmington and Weldon Railway. These operations were somewhat delayed by a raid made by the Confederate General Early, through the Shenandoah Valley to Washington in July; this movement necessitated the detachment of the Cavalry Corps and the VIth Corps to operate against this force. The VIth Corps rejoined the army after the decisive battle of Cedar Creek, near Winchester, October 19, 1864, in which General Early's force was defeated and dispersed; but the Cavalry Corps did not return until the latter part of March 1865.

In the spring of 1865, the Union armies numbered 125,000, and the Confederate 57,000. General Lee's line was now so extended that he had only about 1½ men per yard of his front, including cavalry and artillery. As the Union army was everywhere in force in front of his line, he was unable to gather a sufficient force to protect his right flank which was *en l'air*. Pickett's Division, detached for this purpose, was defeated on April 1st by the Vth Corps and the Cavalry Corps at Five Forks, and General Lee was obliged to abandon his lines and the city of Richmond. He retreated up the Appomattox; his retreat was, however, intercepted at Appomattox C. H., and, as he was in no condition to assume the offensive, he surrendered April 9, 1865.

This campaign illustrates the advantages of, and the limitations in, the use of field fortifications in active operations. General Grant states that, on the Union side in this campaign, "in every change of position, or halt for the night, whether confronting the enemy or not, the moment arms were stacked the men intrenched themselves. For this purpose they would build up piles of logs or rails, if they could be found in their front, and dig a ditch (trench) throwing the earth forward on the timber. Thus the digging they did counted in making a depression to stand in, and

increased the elevation in front of them. It was wonderful how quickly they could in this way construct defenses of considerable strength. When a halt was made with a view of assaulting the enemy, or in his presence, these would be strengthened, or their position changed under the direction of engineer officers." *

These intrenchments protected the Union armies from counter-attacks when their assaults failed. They also covered the withdrawal of the army and enabled it to make the flank marches, which were finally crowned by success.

The Confederate army was equally expert in intrenching; and confining itself almost wholly to passive defense, it inflicted heavy losses upon its adversary without greatly impairing its own strength. Had there been in command of the Union army a less resolute general, or one in whom the people of the country had less confidence, the great losses of the Wilderness, Spottsylvania, and Cold Harbor might have been fatal to the Union campaign.

As long as the Confederate commander could interpose his army so as to protect his lines of supply, he could continue this mode of warfare; but when, under cover of his intrenchments, the Union commander began to threaten the Confederate communications, the position became untenable. In this campaign the turning movements were largely assisted by the systems of railways and rivers which radiated from Richmond to the north and east, and enabled the Union army to constantly shift its line of supply and keep it in its rear.

Campaign of Plevna.—In the spring of 1877, Russia declared war on Turkey and immediately prepared her armies for an offensive campaign. She had been mobilizing her army corps during the preceding autumn and now had nine corps available for duty. The IVth, VIIIth, IXth, XIth, XIIth, XIIIth, and XIVth, numbering about 270,000 men, were formed into the Army of the South, and two corps, the VIIth and Xth, were left as a reserve about

* Personal Memoirs of General Grant, Vol. II. p. 205.

Odessa. The army began the campaign in the latter part of April and having traversed Roumania crossed the Danube in the latter part of June, the XIVth Corps at Braila, and the others at Sistova. The principal Turkish armies available for defense were the Army of the East, 100,000 men, under the Sirdar-Ekrem (Commander-in-Chief) Abdul-Kerim in the Bulgarian quadrilateral, occupying the fortresses of Rustchuk, Schumla, Silistria, and Varna; the Army of the West, 60,000 under Osman Pasha at Widin, with detachments guarding the Danube from Nikopolis westward; and the Army of the Reserve, 25,000, under Suleiman Pasha guarding the passes of the Balkan Mountains which separate the valleys of the Danube and Maritza rivers. The principal of these passes are the Orkhani, the Shipka, and the Elena [Pl. IX, A].

After crossing the river, the XIIth and XIIIth Corps reinforced by a part of the XIth Corps were formed into the Army of the Lom, strength 105,000 men, and were engaged, until the fall of Plevna, in keeping in check the Turkish Army of the East. The VIIIth Corps with a special advance guard under General Gourko advanced by way of Tirnova to Shipka Pass, secured possession of the pass about July 20th, and remained there, defending it against attacks of the Army of the Reserve, until the fall of Plevna. The IXth Corps was sent west to open the Danube as far as Nikopolis, and to check the advance of the army under Osman Pasha. On hearing of the crossing of the Danube, Osman Pasha received permission to concentrate his army and to move to the defense of the Balkan mountain passes, but the capture of Nikopolis by the IXth Corps, and the attempt of this corps to seize Plevna, led to his movement to that town.

Plevna was an unfortified town of 17,000 inhabitants, which owed its importance to its being the center of a radial system of highways leading to Nikopolis, Biela, Tirnova, Shipka Pass, Philippopolis, Sophia, and Widin. It is near the Vid River, about twenty-five miles south of the Danube, and about fifty miles west of the main line of

operations of the Russian army, which ran from Sistova to Tirnova. The town lies in a deep valley formed by the Toutchenitza Creek near its junction with the valleys of the Saluklia, Grivitza, and Bukova [Pl. X]. These valleys, with the Vid, divide the battle-field into five sectors: No. 1, between the Vid and Bukova, known as the heights of Opanetz, which command the highway and bridge leading from Plevna to the west; No. 2, between Bukova and Grivitza, known as the heights of Janik Bair, and also as Grivitza heights; No. 3, between the Grivitza and Saluklia creeks; No. 4, between the Saluklia and Toutchenitza creeks; No. 5, between the Toutchenitza Creek and the Vid River. The hills between the village of Krishin and Toutchenitza Creek are covered with vineyards, and called the Green Hills. They consist of three distinct crests, separated by valleys running east and west.

Osman Pasha reached Plevna with his advance-guard on the evening of July 18th, and on the following day the Russians were seen advancing on the roads leading from Nikopolis to Plevna and Grivitza. A position was hastily taken up with the left resting on the heights of Opanetz, and the right extending along the Grivitza heights; an unsuccessful attack was made this day by the advance-guard on the western end of the Grivitza ridge. The position was held by the Turks, and on the following day was again attacked by the entire force [Pl. X]. The principal attack was again made on the roads east of Bukova; secondary attacks were made at Opanetz, near the village of Grivitza, and a cavalry attack along the valley of Saluklia Creek; all these attacks were repulsed. The opposing forces on this day were Russians, 10,000 with 46 guns; Turks, 14,000 with 58 guns. The Russian advance-guard fell back on the IXth Corps, whose commander, General Krudener, was directed to take Plevna as soon as possible. For this purpose he was sent reinforcements from the IVth and XIth Corps.

Osman Pasha, appreciating the value of his position,

began intrenching it immediately after the battle of July 20th, and to cover his communications sent a force southward to recapture the town of Lovtcha, which had been taken by the Russian cavalry. His army at Plevna was increased to 20,000 men and 58 guns, and was organized in three divisions of nearly equal strength; the first was charged with the northern defenses, the second with the eastern and southern, and the third was held as a general reserve. Ten days later, when the Russians made their second attack [Pl. XI], sector No. 1 was occupied by two small redouts, which were armed with four guns and were connected by shelter-trenches; two guns also commanded the valley and the bridge over the Vid. In sector No. 2 there was a line of shelter-trenches with batteries for nine guns, along the crest of the Grivitza heights, terminating above Grivitza in a square redout for a battalion of infantry and four guns. The redout was surrounded by shelter-trenches which extended to Grivitza Creek. In sector No. 3 there were some kneeling shelter-trenches at the site of Ibrahim Bey redout, protected in rear by batteries mounting six guns. In sector No. 4 there were no works; and in sector No. 5 there was a battery of two guns, with some shelter-trenches near the town of Plevna, commanding the approaches from the south. Near the headquarters was a battery of six guns, protected by a strong line of shelter-trenches, which swept the approaches of the Grivitza redout.

The second attack on Plevna was made on July 30th and consisted of two main attacks made upon the Grivitza redout No. 1 by the IXth Corps, and upon the intrenchments in sector No. 3 by portions of the IVth and XIth Corps, while demonstrations were made in the first and fifth sectors by the cavalry. Although both attacks were preceded by heavy bombardments, the Russians were unable to take the Grivitza redout or the intrenched batteries in rear of the Ibrahim Bey redout. In their defense the Turks did not confine themselves to passive

operations, but attacked the Russian columns in flank whenever an opportunity occurred. The Russian force engaged in this attack numbered 32,000 men with 170 guns, and was one-half greater than that of Osman Pasha.

The situation of the Russian army after the second battle of Plevna is shown in Pl. IXA; it was unable to move forward without leaving a Turkish army on each flank of its communications. It became absolutely necessary to dislodge or destroy either the Army of the East or the Army of the West. The latter was decided on, and the Russian force in front of Plevna was reinforced by the remainder of the IVth Corps and the Army of Roumania, which brought its strength up to 95,000 men and 452 guns. After the second attack Osman strengthened his line throughout by constructing new redouts and new lines of shelter-trenches [Pl. XII]. The most important of these works were in sector No. 2, Grivitza redout No. 2, four hundred yards from No. 1; in sector No. 3, Ibrahim Bey redout; in sector No. 4, Omer Bey redout; in sector No. 5, the line of redouts making the arc of a circle south of Plevna. Sector No. 1 was occupied by two battalions and six guns; sector No. 2 was occupied by seven battalions and nine guns along the crest of the Grivitza heights, and three battalions and six guns in the Grivitza redouts; sectors Nos. 3 and 4 were occupied by eighteen battalions and thirty-two guns; sector No. 5 was occupied by eight battalions and nine guns. The remaining troops, seven battalions with eight guns, constituted the general reserve and were stationed near the headquarters. The strength of his army was now 35,000 men and 72 guns.

After bombarding the Turkish works for several days, the third assault on Plevna was made on September 11th, at three points. The Grivitza redouts were attacked by the Roumanians, assisted by a part of the IXth Corps; Omer Bey redout by the IVth Corps; and the redouts southwest of Plevna by a special column commanded by General Skobeleff who had, in the preceding days, succeeded in establishing himself on the Green Hills east of Krishin. By a

very determined effort, Grivitza redout No. 1 was taken about sundown, after one assault had been repulsed. The Roumanians assaulted, but were unable to capture, the second redout. After several assaults, the Russians were able to penetrate into the Omer Bey redout, but were almost immediately driven out by reinforcements sent from sector No. 3 at this critical moment. In sector No. 5 the attack was pushed vigorously, and was so well conducted that the assailants succeeded in carrying the two redouts nearest to the village of Plevna, but were unable to take any of the remaining redouts in this sector. The small reserve of Osman Pasha was exhausted early in the day, and when the southwestern and one of the Grivitza redouts were taken late in the afternoon, there were no troops available for a counter-attack. The Grivitza redout was not a serious loss, as it was commanded by the redout No. 2. The loss of the redouts south of Plevna was, however, a very serious one; if the Russians could hold and strengthen these as a base for further operations, Plevna would have to be evacuated. A determined effort was therefore made on the 12th to recapture them; the first attack failed, but a second made in the afternoon was successful, and the Russians were driven out. The other redouts of this sector, remaining in the possession of the Turks, prevented the Russians from sending reinforcements to the garrisons of the captured works. General Skobeleff was now ordered to evacuate his position, and the Turks immediately followed and intrenched the Green Hills about Krishin, which were now recognized to be one of the key-points of the position.

In the first battle of Plevna the Russian casualties were 2,845 men killed and wounded; in the second, 7,305 men; in the third 18,581 men: making a total of 28,731. The Turkish casualties are not known, but must have been very much smaller.

Upon the advice of General Todleben of the Russian Engineers, the defender of Sebastopol, general attacks

were now abandoned, and the Russian army began the construction of an investing line of intrenchments which was to confine the Turkish army [Pl. XIII]. Wherever possible, these lines were pushed up close to the Turkish lines, so as to keep the garrison constantly on the alert. To complete the investment, two more corps were sent from Russia, the Russian Guards and Grenadiers. While awaiting their arrival a cavalry division was sent west of the Vid to cut the Turkish communications. Osman Pasha realized the dangers of his position and, to preserve his communications, requested permission to evacuate Plevna and to fall back toward his base, Orkhani. This was refused, but the Turkish government promised to see that his army was supplied, and his communications kept open. A reinforcement of 9,000 men with 500 wagons reached Plevna in the latter part of September, and a convoy of 500 wagons early in October. To enable future convoys to reach the place, stations on the way to Orkhani were garrisoned and fortified by Osman; Dolni-Dubniak with five battalions and two guns, Gorni-Dubniak six battalions and four guns, Telitch six battalions and four guns.

The Russian reinforcements began to arrive in the latter part of October, and on the 23d of that month Osman's communications were cut by the capture of Gorni-Dubniak and Telitch; the garrison of Dolni-Dubniak was withdrawn to Plevna. During the month of November the Turkish lines on the south were extended to the Vid, and the Russian lines were advanced to within a few paces at the Grivitza redout, where the Roumanians were engaged in a regular siege, and within a hundred yards in other parts of the line. Assaults were made from time to time to drive the Turks from their advanced lines, and thus shorten the line of investment. Since the Turkish army was being gradually starved, it was decided, at a council of war held on the last of November, to make a grand sortie on the 8th of December with all the available forces.

The attempt was made on the 9th of December, the Turks attacking the investing lines west of the Vid River. The lines were, however, too strong and too well guarded to be carried, and on the 10th of December Osman Pasha surrendered. At this time the Russian army numbered 120,000 men with 585 guns, while the Turkish army numbered 45,000 men with 60 guns.

The operations around Plevna emphasize the lessons of the Virginia campaign; that front attacks on well intrenched lines have little chance of success, and that a defensive line can be held only so long as its lines of retreat and supply are secure. They also show that a well situated and intrenched strategical point may seriously embarrass and endanger the operations of an invading army.

CHAPTER XII.

CONSTRUCTION OF FIELD FORTIFICATIONS.

INTRENCHING TOOLS AND THEIR TRANSPORTATION.

Proper tools for the construction of field fortifications should form a part of the equipment of every field army.

These intrenching tools are of two general classes; those carried by the individual soldier, and those transported by wagons or on pack mules. The *portable tools* of infantry are the intrenching spade, the intrenching pick, the hatchet, the flexible saw, and the wire-cutter. The *intrenching spade* [Pl. XIX, Fig. 71], is some modification of the Linneman spade and in its case weighs about 2½ pounds. To make it a complete intrenching tool, suitable for wood as well as earthwork, the sides of the blade are sometimes given saw and knife-edges. In foreign services it is made ½ meter long so that it can be used as a measuring-rod; in our service its length should be either ½ yard or 2 feet. The *intrenching pick* [Pl. XIX, Fig. 72], weighs from 3 to 4 pounds; one end of the blade is made in the form of a hatchet and the other in that of a pick. It is used in loosening hard earth, making loopholes in walls, felling trees, etc. The common *hatchet* is 12 to 15 inches long and weighs 2½ pounds. The *flexible saw* [Pl. XIX, Fig. 73], is about 4 feet long and is made of twelve saw-toothed links so riveted together that it can be folded up and carried in a small case. It may be used for cutting timbers less than one foot in diameter. *Wire-cutters* [Pl. XIX, Fig. 74], are used in destroying wire fences and in constructing or destroying wire en-

tanglements. Those used in the military service should be small and of great power; the Bernard wire-cutter, shown in Pl. XIX, fulfils these requirements. In carrying these tools the cases are either slung from the shoulder or attached to the waist belt. The cavalry carry intrenching spades, hatchets, wire-cutters, and explosives and fuses for destroying lines of telegraph and railway. The portable tools of the engineers, and the infantry and cavalry pioneers are the ordinary spade, pick, and axe. Ordinary spades are of two classes; the long-handled is used for deep excavations and the short-handled for other work. In our service no portable tools for the infantry have as yet been adopted; the soldiers usually employ the bayonet and a tin cup or plate for hasty intrenchment. Toward the close of the Civil War General Benham, who commanded the Engineer Brigade of the Army of the Potomac, feeling the want of such a tool, invented a small intrenching spade. Its length is 22 inches and its weight 1½ pounds. Since that time experiments have been made with trowel bayonets, trowel intrenching tools, and hunting knives.

In wagons or on pack animals there are carried, for infantry, ordinary spades, picks, axes, hatchets, and saws; for cavalry, ordinary spades, hatchets, and portable magneto-electric machines, fuses, and explosives for destroying bridges, etc.; for artillery, ordinary spades, picks, axes, and hatchets, besides the tools carried in the forge and battery wagon; for engineers, ordinary spades, picks, axes, saws, and all tools necessary for carpenters' and miners' work in the field. The pontoniers have charge of the wagons containing the reserve tools of the army.

In the United States army there are no regulations governing either the number or the character of the tools carried by a field army. In the Army of the Potomac, toward the close of the Civil War, a small bridge train of three companies of volunteer engineer troops was assigned to each army corps, and a reserve train of the regular battalion of engineers accompanied the army headquarters.

These troops had charge of the intrenching tools of the army, six tool wagons being allowed to each army corps. A pioneer detachment of infantry soldiers under the command of a lieutenant was organized in each brigade, and the brigade detachments of a division consolidated under the command of a captain. The pioneers numbered two per cent of the command; each man carried an axe, pick, or shovel in place of his knapsack, which was transported in a wagon.

In the future it will probably be necessary to adopt a system similar to that of one of the Continental armies; that of the German army is given on the following page, as a type.

A German infantry division is composed of twelve to seventeen battalions, one cavalry regiment, six batteries, one company engineer pioneers, and one division bridge train. The number of intrenching tools both large and small carried by a German infantry division is about equal to one-half the strength of the command. The fighting strength, including non-commissioned officers, of a battalion is 960 rifles, of a cavalry regiment 528 lances and carbines, of a battery 6 guns, and of a company of engineer pioneers 195 rifles. A cavalry division is composed of twenty-four squadrons and its pioneer detachment of from four to six men per squadron.

HASTY INTRENCHMENTS.

Although the selection of a position and the distribution of the troops along the line may be influenced by the possibility of rapidly strengthening it by field fortifications, these matters properly belong to the domain of strategy and tactics. The line of defense is chosen by the army, corps, and division commanders, each of whom has one or more engineer officers on his staff. Hasty intrenchment begins with the troops in position. The working unit is the infantry company, which usually intrenches itself; it may be assisted by the engineers, when it is necessary to organize a point of support.

INTRENCHING TOOL ORGANIZATION OF THE GERMAN ARMY.

Troops.	For Earthwork.				For Woodwork.			Additional Tools.
	Spades.		Picks.					
	Large.	Small.	Large.	Small.	Axes.	Hatchets.	Saws.	
Battalion of infantry:								
Carried by men		400		40		20		
Carried in wagons	20		10		8	14	4	
Total	20	400	10	40	8	34	4	
Regiment of cavalry:								
Carried by men		32				48		Tools and explosives.
Carried in wagons	8					10		
Total	8	32				58		
Pioneer detachment of a cavalry division:								Tools, supplies, and explosives for repairing and destroying bridges and railways.
Carried by men	13		6		8	3		
Carried in wagons	1		1		12		4	
Total	14		7		20	3	4	
Battery of field-artillery:								
On the gun-carriages	6		6			12		
In remaining carriages	23		12		14	24		
Total	29		18		14	36		
Company of pioneers:								
Carried by men	88		44		45	18		Carpenters' and miners' tools and supplies.
Carried in tool wagons	60		30		20		12	
Carried in other wagons	2		2					
Total	150		76		65	18	12	
Division bridge-train:								
In 3 tool wagons	600		150		90		30	Carpenters', blacksmiths', etc., tools and supplies.
In train wagons	14		14		3	15	3	
Total	614		164		93	15	33	

Tasks.—The time which is required for the construction of shelter-trenches depends upon the character of the tools, the soil, and the task of each relief. Shallow trenches can be executed as rapidly with an intrenching as with an ordinary spade, but deep trenches require one-third to one-half more time. In medium soil with an ordinary spade an unskilled workman can excavate one cubic yard of earth in one hour; in hard soil he will require two hours, and in frozen ground three or four hours to accomplish the same task. Four cubic yards is considered a fair day's task for an infantry soldier; of this amount one yard can be excavated in the first hour, two yards in two and a half hours, and three yards in five hours. For quick work with infantry troops there should always be two or more reliefs; each works twenty minutes if the task is to be done with the intrenching spade, and thirty minutes to four hours if the work is to be done with the ordinary spade.

Shelter-trenches.—For hasty intrenchment the men may be placed at intervals of one yard, but it is usually better, especially when working with ordinary tools, to place them at intervals of five feet or two yards. Two twenty-minute reliefs would then construct a kneeling trench; two one-hour reliefs, a standing trench; and two two-hour reliefs, a complete trench if the material is all thrown into the parapet; if a part is thrown to the rear the time may be shortened. If tools are plentiful each man is given a spade and pick, otherwise men with picks are distributed along the line of spaders. In constructing a shelter-trench, the front and rear lines of the trench are marked upon the ground with a pick, under the direction of one of the company officers, who is careful to so adjust it that the foreground can be seen from every point of the line, when he places his eye at the proposed height of the crest of the parapet. He also sees that his line connects properly with the trenches on either side and allows a pace or yard for every rifle in the firing line. The ends of discontinuous trenches, whether company or bat-

talion, are plainly marked with pegs. If traverses are to be constructed for protection against enfilade fire, they are traced before any excavation is made.

A company assigned to the construction of a shelter-trench is divided into two reliefs, each under the charge of a lieutenant; and each relief into working squads composed of men equipped with shovels and picks under the charge of a non-commissioned officer. The first relief is marched to the line and deployed at two-pace intervals; at an adopted signal each man outlines his task and begins excavating at the front line of the trench. The non-commissioned officers see that the trench and parapet are continuous, and that they are given the proper dimensions. The second relief is formed at the proper time and is ready to replace the first relief when its time expires. If there is but one set of tools for both reliefs, the first relief leaves its intrenching tools in place. If there is danger of interruption by the enemy, the working parties of a battalion are protected by outposts taken from the reserve company, and each man carries his rifle and equipments, which he places on the ground immediately behind his task, the rifle being laid with the muzzle to the rear. While one party is at work on the trenches, another is organized for clearing the foreground so that both operations are completed simultaneously. The construction of obstacles and overhead cover is only attempted after the foreground is cleared, and the shelter-trenches are finished.

A rough estimate of the time required and the organization of the working parties for hasty intrenchment is given in Appendix A.

Lunettes.—If a lunette, for two companies of one hundred men each, be constructed similar to the French lunette for one company [Pl. VIII, Fig. 66], the faces will each measure 25 yards, the flanks 13 yards, and the gorge trench 25 yards. The interior crest of the faces and flanks is traced upon the ground by selecting the salient and directing the faces so that they can thoroughly sweep the

ground over which the assailant must attack. The flanks are so directed that they can flank the adjacent parts of the line. The interior crest having been located in plan, is fixed in elevation by driving stakes at the angles, the extremities, and at intervals along the line, and attaching cross-pieces to them at the proper height. The line is then carefully examined with a view to discovering any dead spaces which may exist in front of the work. The interior crest being fixed, the limiting lines of the parapet, the trench, and the ditch are marked upon the ground, and stakes are driven to indicate the height of the exterior crest. The gorge trench is traced as described above, and located where it will not be exposed to the view of the assailant, but where it can sweep with its fire the interior of the work. In tracing this lunette it is not essential that either the two faces or the two flanks should be equal to each other.

The work is executed with ordinary intrenching tools, the workmen being divided into three squads; one excavates the ditch of the main work, one the trench, and the third constructs the trench along the gorge. If the profile Pl. I, Fig. 6 is adopted for the main work and profile Pl. I, Fig. 4 for the gorge trench, fifty spades will be required in the ditch, forty-six in the trench, and fifteen in the gorge, if the earth is soft and the tasks are five feet in length; twenty-eight picks are added for ordinary earth, making a working party of one hundred and thirty-nine men. A reserve of 10 per cent is added to level the parapet, for extra work, and as substitutes; the total working party is therefore one hundred and fifty-three men.

As the number of privates in a company is eighty-four, the work could be done by two companies unless the tasks are too great to be executed in the given time. The amount of each task in the ditch is $1\frac{3}{4}$ cubic yards, and in the trench $3\frac{3}{4}$ yards. The work could therefore be executed in ordinary soil by two companies in one day, but it would be better to employ an entire battalion and execute

the work in two reliefs. The supernumerary men could be employed in clearing the foreground and in constructing obstacles, in which work they would be assisted by the squad which excavated the ditch as soon as it had completed its excavation.

Redouts.—A field redout for two companies, similar to the German redout, requires an interior crest of about 130 yards. If the site is cleared of obstructions, it is easily adjusted to the ground by having men, at intervals of 10 or 15 yards, hold a long cord. By shifting the positions of the men, and by holding the cord at the proper height above the ground, the officer in charge fixes the crest so that the exterior ground is properly swept. The men are then replaced by stakes, and the work of tracing, profiling, and excavating is carried on as described in the construction of the lunette. Profile Pl. IA, Fig. 7*a* is used for the faces and flanks, and that, or profile Pl. I, Fig. 4 for the gorge. A separate squad is required for the parados, which covers the gorge and shelters its defenders from the fire of the assailant which grazes the faces and flanks. A battalion should be assigned to the construction of a field redout for two companies. Engineers, if available, are utilized for superintendence and for the construction of the obstacles and bomb-proofs.

DELIBERATE FIELD-WORKS.

The Plan.—In the construction of deliberate works, a preliminary survey may be made to determine the contours of the site, or the work may be planned to fit an accurate contour map already in the possession of the engineer. If there are any bench-marks on the site or map, they are transferred to the drawing of the fortification and the work is laid out by means of them. A foot reconnaissance with a plotting board may replace the survey, when there is not sufficient time. In some cases it will be necessary to begin the construction of these works without any previous mapping of the ground; it is then

essential that the distances and directions to the adjoining works be indicated from some central position in the proposed work, as well as the probable direction of attack. These will assist in locating the faces so as to sweep the approaches, the flanks to sweep the approaches to the adjacent line or neighboring works, and the gorge so that it is not exposed to reverse fire.

Profiles.—The selection of a profile for the work is determined by the desired command, probable exposure to fire, and the character of the soil in which the work is constructed; the cuts and fills may be approximately equal to each other in profile, or the total excavation may be equal to the total embankment. To design a profile in which the cuts and fills are equal, the height of the interior crest and depth of trench having been assumed, the profiles of the parapet and trench are designed to fulfil the requirements given in Chapter II, and their areas computed. The difference between these gives the area of the ditch; its form is obtained by assuming either the width or the depth and computing the other dimensions.

To design a profile in which the excavations and embankments are equal, the profiles of the parapet and trench are designed as described above, their areas computed, and the position of the center of gravity of each determined. Their volumes are each equal to the area of the profile multiplied by the length of the trace of the center of gravity between the end sections; the difference between these volumes is the volume of the ditch. Assuming the general form of the ditch, the position of the center of gravity and the length of its trace between end sections can be determined, and hence the area of its profile. Having the area of the profile, the form of the ditch is determined as explained above.

Tracing.—Before the work is traced upon the ground, the site is cleared of such brush, trees, and obstructions as would interfere with this work. The plan is then trans-

ferred from the drawing to the ground by locating the interior crest with stakes. If traced without drawings it is done in the manner described for field lunettes and redouts. The work may be tested by sighting over a cord attached to the stakes at the height of the interior crest. From the interior crest the projections of the limiting and other principal lines of the ditch, parapet, and trench are fixed on the ground with pegs, tracing tape, or furrows made with a pick. The perpendicular distances between these lines are taken from the plan or profile.

Profiling.—The object of profiling is to guide the workmen in the construction of the work; the number of profiles required depends upon the degree of intelligence of the workmen and supervisors, and their familiarity with fortification work. A profile [Pl. XIX, Fig. 75] is a stout frame, showing the dimensions and slopes of the parapet, which is erected on the site of the parapet to guide the workmen. It may be constructed in place, but it is ordinarily put together where suitable material is found, and simply erected in place by fastening it to stakes driven into the ground. One or more of the strips of the profile are so placed that they will be horizontal when the frame is erected; the frame is adjusted in place by laying a level upon them. The inclinations of the slopes of the trench and ditch are indicated by inclined pieces [Pl. XIX, Fig. 75], which are fastened to stakes. As the excavation progresses, the slope is tested by laying a straight-edge upon the inclined face.

Excavation of the Work.—The ground is first cleared of all brush, stumps, or stones which would interfere with the work, and, as in other excavations, the ground in the ditch and the trench may be loosened with a plow; the plow should be used before the profiles are erected, otherwise the profiles are liable to be broken. The ditch and trench are each divided into tasks 6 feet long [Pl. XIX, Fig. 76], and the picks and shovels are distributed as

shown in Pl. XIX, Fig. 77. A skilled workman can throw earth 12 feet horizontally, and lift it 6 feet vertically; for an unskilled workman these distances should be decreased to 10 and 5 feet respectively, or even less. When earth is removed beyond these distances, there must be a relay of shovelers to move it. With the above data, the total excavation in the profile is divided into two or more reliefs, each of which has a definite task; a reserve of 10 per cent is kept to furnish substitutes for the original details.

The task for unskilled men should not exceed four hours of fair work; each relief should be allowed to leave the work as soon as its task is finished.

The workmen excavate ditch and trench in layers one or more feet thick, beginning at the side nearest the parapet, and leave the scarp and counterscarp in steps, as shown in Pl. XIX, Fig. 75. In deep ditches, the step at half depth is two or more feet wide, to act as a bench for the transfer of material from one relay to another. A special squad is detailed to roughly shape the parapet. If all the earth is excavated from the ditch, the revetment squad begins the revetment of the interior slope when the parapet reaches the height of the banquette tread; if part of the material is excavated from the trench, the squad only places its anchoring logs and wires during the excavation of the trench, and finishes the revetment when the trench has been completed. If bomb-proofs are to be placed under the parapet, or drains through it, they should be constructed before the work on the parapet is begun. These are usually constructed by the engineers, who also supervise the work done by the infantry. In organizing squads of volunteer soldiers for fortification or other engineering work, it is advisable, as far as possible, to assign each man to work similar to that which he has been performing in civil life. In this way, much more can be accomplished than by detailing the men by chance.

Deliberate works are frequently constructed by civilian

labor. For ordinary work on the defenses of Washington, the laborers were divided into squads of thirty to fifty men under a competent foreman, and in a similar manner squads of carpenters under a master carpenter were assigned to the construction of timber work in each fort. These men, being accustomed to the labor, worked eight to ten hours a day.

CHAPTER XIII.

PASSAGE OF RIVERS.

When an army in the field finds its march interrupted by a river, it may effect the passage of this obstacle by fords, on ice, by ferries, or by military bridges. The selection of the place and means of crossing are determined by a reconnaissance, which should be as detailed and extensive as circumstances will permit.

FORDS.

A river with a moderate current may be forded by infantry when the depth does not exceed 3 feet, and by cavalry and carriages when its depth is not over 4 feet. For carriages whose contents are injured by water, the depth should not exceed 2½ feet.

The requisites of a good ford are that the banks should be low but not marshy, the water attain its greatest depth gradually, the current be moderate, the stream not subject to sudden freshets, and the bottom even, hard, and tenacious. In mountainous countries the bottom is frequently covered with large stones, which render the passage of carriages nearly or quite impracticable. In level countries the bottom is frequently either mud or quicksand, and impassable for both men and carriages. Sometimes the bottom is composed of fine sand which is sufficiently hard, but which, by the action of the hoofs of the animals and the current, is stirred up and washed away, increasing the depth until the stream becomes unfordable. The best bottom is one of coarse gravel.

Fords are usually found in the wider, and also in the more rapid parts of a river. Their position may be determined by sending a number of mounted men across, wherever there is a probability of the river being shallow. The most certain method is to float down the stream in a boat, keeping it in the swiftest part of the current, where the stream is usually the deepest; when a sounding line of the proper length, hung over the stern, touches bottom, the river is sounded across. When a ford is discovered the prominent objects on the shore should be noted so that the place may be easily recognized; a graduated stake should also be planted at the water's edge, in order that any variation in its depth may be ascertained. Rivers which are not fordable may sometimes be rendered so by sinking a mattress of fascines or brush, loaded with stones and gravel. There have been instances of rivers rendered fordable by diverting a part of the water from its natural course.

When the stream is wide and rapid, the ford must be carefully examined and staked out. The troops pass in column, with sufficient intervals to avoid choking the current. When boats are available, a few should be stationed below the ford to assist men who may be carried down by the current. When boats are not available this duty may be performed by mounted men, or by a life-line supported on casks or other floats. After a freshet, the ford should be reëxamined, to discover any alterations which may have taken place in the bed of the river.

In marching in retreat, it is advisable to destroy a ford after having used it. This may be effected by digging trenches across it, or by placing in it harrows, planks filled with spikes, barbed wire, crowfeet, etc.

ICE.

In high latitudes during winter, rivers are frequently covered with ice of sufficient thickness to sustain the heav-

iest loads. This means of communication should be used with great circumspection, since a change of temperature may not only destroy this natural bridge, but render the river impassable by any means, for a considerable time, on account of floating ice. The requisite thickness of ice to allow the passage of infantry in single file, with two-yard intervals, on a line of planks, is 2 inches; cavalry or light guns, with intervals, 4 inches; field-guns unlimbered and on sleds, 5 inches; field-guns limbered and drawn by horses, with intervals between pieces, 6 to 7 inches; the heaviest loads of an army train, 10 to 12 inches. When there is any doubt as to the strength of the ice, tracks of planks may be laid for the carriage wheels, or the carriage may be transformed into a sledge by fastening planks under the wheels to distribute the load over a greater area.

FERRIES.

Boats.—The point of passage being selected, all the boats that can be procured are collected at that place; they are then arranged along the shore according to size, and numbered.

The infantry is divided into sections, depending in size upon the capacity of the boats in which they are to embark, and each section is provided with the number of its boat; great care must be taken not to overload the boats or to crowd the boatmen. The soldiers enter the boats one by one, alternately against the right and left gunwale, and are cautioned not to stir from the places assigned to them, and above all not to spring up when the boat lurches; they disembark in the same manner. The point of debarkation is usually below the starting-point, as heavy boats will drift with the current. When the river is shallow near the shore, the loaded boat must not approach the bank near enough to ground.

In the passage of artillery, it is usually necessary to dismount the guns.

Horses are not often passed over in boats, since they may be made to swim. When boats of sufficient size are available, the bottoms are covered with planks, and the horses are placed crosswise, facing alternately up and down stream, so that they may not be thrown down by the rolling of the boat.

Rafts.—When a sufficient number of boats is not available, rafts are made of lumber, casks, and other suitable materials. A small raft may be made of a wagon-box, covered with canvas or inverted over a number of empty casks. A *floating bridge* is a raft made of two boats covered with a strong platform. Not only artillery and cavalry may be transported by this means, but also infantry in much greater numbers than by using the boats separately. The floating bridge can be maneuvred by oars with nearly the same facility as a boat.

Rope Ferries.—The rope ferry, used in streams with sluggish currents, consists of a raft, a floating bridge, or a wide scow, drawn along a rope stretched across the river, by hand, or by an oar with a notch cut in the lower edge of the blade to grasp the rope.

Trail Bridges.—[Pl. XXII, Fig. 90.] The trail bridge is employed over streams not more than 150 yards wide, with a current not less than one yard per second. A cable is stretched across the river above the surface of the water and is drawn taut by means of a windlass, blocks, and falls. A trail rope from the boat or raft is attached to a pulley which runs on the cable ; and the boat is given such a position that its sides make an angle of about 55° with the direction of the current. This may be accomplished by attaching the trail rope at the proper point on the gunwale of the boat, by means of a rudder, or by means of maneuvring ropes attached to the pulley.

The normal component of the force of the current acting on the side of the boat may be divided into two components; one, perpendicular to the cable, which is neutralized by its resistance ; the other, parallel to it, which causes

the boat to cross the stream with a velocity depending upon the strength of the current.

The most suitable raft for a trail bridge is a floating bridge composed of two long, narrow, and deep boats with nearly vertical sides. The interval between the boats is such that the current acts on the sides of both throughout their entire length.

Flying Bridges.—When the river is more than 150 yards in width, or it is desirable not to impede navigation, the trail rope or cable is anchored in the stream or is attached to a tree on an island, instead of being attached to a cable connecting the shores, as in the trail bridge. The maneuvring ropes are attached to the trail rope which is supported by several floats, small boats, barrels, logs, etc. When an anchor is used, the first float should be as near to it as possible without raising it; the others should be arranged to maintain the rope above the water. The flying bridge is moved by the action of the current, in the same manner as the trail bridge; its path is the arc of a circle, however, instead of a right line. The trail rope is anchored in the middle of the stream, when the current is strongest there; otherwise it is anchored on the side of the weaker current. If no floats are used, the rope is passed over a tripod on the raft, to keep it from dragging in the water.

Rope ferries, trail, and flying bridges furnish the means of passing any stream. They may be established in a short time and with such materials as can be found in the vicinity. They permit the passage of troops of all arms and of the heaviest loads, and are not liable to injury from ordinary floating bodies.

BRIDGES ON FLOATING SUPPORTS.

Military Bridges.—A bridge is composed of two parts; the floor system comprising the roadway bearers, joists, or planks, and side-rails, and the supports which sustain

the floor system. In military bridges the floor joists are called *balks;* the floor planks, *chess;* and the spans between two consecutive floating supports, *bays.* Bridges are classified according to their supports; these may be either *floating*, as ponton, ordinary boat, or raft bridges; or *fixed*, as trestle, crib, frame, truss, and suspension bridges.

Width.—The width of a bridge for infantry in single file should be 1½ to 3 feet; for infantry in double file, cavalry in single file and light wagons, 6 feet; for army columns, 10 feet; for double columns, 16 feet. The head room of through bridges should be at least 10 feet.

Loads.—The greatest load to be sustained by a military bridge is practically that of a country highway bridge, viz.:

1st. Its own weight.

2nd. A live load, which for the floor system is 80 pounds per square foot of total floor surface between side-rails, or five tons on the wheels of a carriage whose wheel base is 5 feet by 8 feet; for the supports, the live load is 80 pounds per square foot of total floor surface for all spans up to 75 feet, and 50 pounds for all spans over 200 feet; for intermediate spans, proportionate amounts.

Approaches.—The grade of the approaches should never exceed 6 per cent, and if possible should be less than 4 per cent.

Ponton Bridges.—The bridge equipage of the United States Army is composed of reserve and advance-guard trains. The former are intended to accompany large bodies of troops in the field, and are provided with materials necessary for the construction of bridges of sufficient capacity to pass large armies, with their heaviest trains, over rivers of any size or rapidity.

The advance-guard trains are intended for the use of light troops, such as advance-guards, cavalry divisions, etc. They are organized, both as regards material and carriages, with a view to rapidity of movement and to fulfil all the requirements of troops engaged on such service.

Reserve Equipage.—Organization.—This equipage is divided into *trains*, each of which is composed of four or more *ponton divisions* and one *supply division;* each division is accompanied by a tool wagon and a traveling forge. Each ponton division is complete in itself, containing all the material necessary for constructing a bridge of eleven bays, 225 feet in length. One ponton division should accompany each army corps.

Each ponton division is subdivided into four *sections*, two of which are *ponton* and two *abutment sections;* each ponton section contains one *chess* and three *ponton wagons;* each abutment section, one *ponton*, one *chess*, and one *trestle wagon.* The ponton wagon carries a ponton and the balks and side-rails for one bay; the trestle wagon carries a trestle and the balks and side-rails for two bays; the chess wagon carries chess for three bays.

The ponton section contains the material for three bays, and should never be subdivided. The division, however, may be increased or diminished at pleasure, by changing the number of its ponton sections.

Bridge Materials.—The *Birago trestle* [Pl. XXI, Fig. 84], is composed of a *cap* (A), two *legs* (B), two *false legs* (C), two *shoes* (D), and two *suspension chains* (E).

The *ponton* [Pl. XX, Fig. 78] is a large flat-bottomed wooden boat, which has a buoyancy of about 9½ tons, and a capacity sufficient to transport forty men, fully armed and equipped, besides its crew of pontoniers.

The *balks* are of two kinds [Pl. XX, Fig. 78]. The long balk is of white pine, 27 feet long, and 5 inches square; 8 inches from each end is fastened a cleat or claw which rests against the side of the ponton boat or trestle cap. The trestle balk is similar, but only 21 feet 8 inches long. Extra balks are used for side-rails.

A *chess* [Pl. XXII, Fig. 90] is a white pine plank 13 feet by 12 inches by 1½ inches; the width at each end for a distance of 2 feet is reduced to 10½ inches, thus forming

notches for the passage of the side-rail lashing. The middle line across the chess is marked on both sides.

The other essential parts of the bridge are the *lashings* or ropes, for fastening the balks to the ponton hooks, and the side-rails to the balks.

Construction.—There are four methods of constructing a ponton bridge: by successive pontons, by parts, by rafts, and by conversion.

In the method *by successive pontons*, all the materials for the floor system are stored near the abutments; the pontons are rowed into position and the bays are completed, in succession, from one or both abutments.

In the method *by parts*, the materials for the bridge are stored along one or both shores above the site, and are formed into parts or rafts consisting of two bays; upon each part are stored the materials of the floor system of another bay. The bridge is constructed by rowing the parts into position successively, and connecting them with the completed portion of the bridge, by means of the materials of the extra bay carried on each part.

The method *by rafts* is similar to that by parts; the end boat of the raft is, however, lashed to the end boat of the completed bridge instead of being separated from it by a bay. The side-rails are spliced by short pieces of wood at the junction of the rafts.

In the method *by conversion*, the materials for the bridge are stored along the banks above the site of the bridge, and the entire bridge is constructed parallel with, and near to, the shore. It is then floated down to the site, and swung into position, pivoting about one of the abutments.

Comparison of the Four Methods.—The method of construction by successive pontons possesses the advantages over the others of being applicable to all streams, of requiring a minimum quantity of material, the fewest men, and the shortest time for its accomplishment. The labor of constructing a bridge by this method increases rapidly

with the number of bays. When, therefore, the bridge is more than forty bays in length, the methods by successive pontons and by parts, are combined. The bridge is commenced, at both ends if possible, by successive pontons, and is pushed on rapidly toward the middle of the stream. The two portions, thus formed, are connected by parts, which are constructed in the meantime along the river bank above the bridge.

The method by rafts may be employed when the bridge is liable to injury from floating bodies, as the portion threatened can be readily disconnected, dropped out of the bridge, and restored to its place when the danger is passed. This method may be employed by an army hard pressed in retreat, as the rafts are easily disconnected when it is desired to destroy the bridge.

The construction by conversion is a delicate operation and can be executed only by well trained men.

Advance-guard Equipage.—Organization.—The trains of this equipage are composed of two or more *ponton divisions*, each of which consists of eight *ponton*, two *chess*, and two *trestle wagons*. One ponton division, carrying the materials for a bridge 186 feet long, should accompany each cavalry and detached infantry division.

The ponton wagon contains all the materials for a single bay. The chess wagon contains chess for three bays. The trestle wagon contains one trestle and the balks and side-rails for two bays. The division may, therefore, be increased by one or more ponton wagons without disorganizing it.

Bridge Materials.—The *ponton* of the advance-guard equipage is a white pine frame covered with canvas. The frame [Pl. XXI, Fig. 87] is composed of two side frames and of twelve narrow and two wide transoms. The frame, when assembled, is held together by a rope passed through rings in the ends of the side frames, and tightened with a rack-stick. The floor is made of chess.

The side frames of the *canvas ponton*, used by the Army

of the Cumberland during the latter part of the Civil War, were divided into two parts which were connected by stout hinges placed on the inside; the frames could thus be folded up to one-half their full length. The object in adopting this form was to dispense with the necessity of special ponton wagons and trains; all the parts of the bridge, except the balks, could be carried without difficulty in the ordinary army wagon. A special wagon was required for the balks, but it was quickly made by throwing off the body of an army wagon and lengthening the coupling. The ponton trains which accompanied the Army of the Cumberland, from Chattanooga to Atlanta, and thence to Savannah and Washington, were composed of hinged canvas pontons, and gave general satisfaction. Whenever a bridge was to be used for more than forty-eight hours, the ponton bridge was replaced by a trestle or crib bridge.

The *balks* are 22 feet long and 4½ inches square; the *chess* are 11 feet long.

The other materials of the advance-guard train are the same as in the reserve train given above.

Construction.—As the canvas ponton can be carried a considerable distance by six or eight men, it is not necessary to unload and assemble the pontons on the river bank. The bridge is constructed by successive pontons, by parts, by rafts, or by conversion as already described.

Abutment Bays.—If the water at a distance of one bay from the abutment is not sufficient to float a ponton, a Birago trestle is used. As the canvas pontons should never be allowed to ground, the necessity for the use of trestles in the abutment bays is more frequent with the advance-guard than with the reserve train.

If the water level is liable to variation, as in tidal streams, a joint is made in the floor system by means of a *saddle* as shown in Pl. XX, Fig. 79, or by fastening the balks of the abutment bay to the nearest gunwale of the first ponton.

Anchorages.—The distance of the anchors from the bridge should be at least ten times the depth of the stream; with a less distance the bows of the ponton sink too deeply in the water. The direction of the cable when made fast to the bridge should be the same as it would assume if riding freely at anchor. The number of anchors will depend somewhat on the strength of the current; it is generally sufficient to cast an anchor up stream for every alternate ponton, and half that number down stream; but where the current is very rapid it may be necessary to anchor every up-stream boat, especially near the middle of the bridge. The number of anchors cannot be much diminished, however moderate the current, as the anchorage has a very marked effect in checking the horizontal oscillation to which bridges are subject when troops are marching over them; for this reason it is frequently advisable to increase the number of down-stream anchors. A down-stream cable is never attached to a ponton that is not anchored up stream.

Draw-bridges.—In navigable streams it is frequently necessary to provide a draw in the bridge; this is effected by introducing two or more rafts, constructed as described in the method by rafts. These rafts are operated by means of cables anchored above and attached to the bridge.

Bridges with Extended Intervals.—In a bridge with extended intervals the balks extend only from the outer gunwale of one boat to the outer gunwale of the succeeding one; the adjacent balks break joints at the boats. This construction has the advantage of making the bridge one-fourth longer for the same number of pontons, but does not give the same strength or stiffness as the ordinary method. It answers, however, very well in small streams, when the bays are all reinforced with additional balks.

Ordinary Boat Bridges.—With some modifications, the principles of construction are the same as those given for ponton bridges. Since the boats are not usually of a

uniform size, the length of the balks for each bay should be proportioned to the capacity of the boat which sustains them, so that the bridge may not be endangered when the bay is crowded with men. The boat nearest to each abutment must be strong and large, and large boats should be selected for the strongest part of the current, so that the intervals may be as great as possible. The bridge will then offer less obstruction to the current, and will also be in less danger from floating bodies. The intermediate boats should increase or diminish in size gradually, so as to avoid a sudden change in the level of the roadway. The gunwales of the boats should be made approximately level. This is effected by cutting down the larger boats or by loading them until they are sufficiently deep in the water; this latter expedient increases the strain on the cable and should not be resorted to in a strong current. In the smaller boats, the gunwales are raised, or a braced trestle is placed in the axis of the boat for the support of the roadway.

When anchors of sufficient size can be procured, the anchoring of an ordinary boat bridge does not differ from that of the ponton bridge. When this is not the case, anchors may be improvised of boxes or panniers filled with stone, of harrows loaded with stone, of a bundle of picks, or by driving piles in the river-bed above the bridge.

Raft Bridges.—A raft employed as a support for a bridge should be at least 35 feet in length and should support a load of 15,000 pounds. If the logs are less than 35 feet in length, a long log is made of two short ones, spliced butt to butt. If the stream is swift, the raft and logs are pointed to reduce the resistance. If constructed of round timbers, the logs are laid with the butts alternately up and down stream, and are fastened together, at the ends and under the roadway, by transoms of 6-inch or 8-inch timbers [Pl. XX, Fig. 80]. Roadway bearers for the support of the balks are spiked to the middle transoms. To neutralize the downward pull of the anchoring cable, the center of the

roadway should be slightly down stream from the center of buoyancy of the raft. In this country, there are few varieties of unseasoned timber that possess the requisite buoyancy for rafts.

Rafts of Casks.—These rafts may be constructed by forming a frame of timbers to contain the casks [Pl. XX, Fig. 81]. The frame consists of four longitudinal pieces halved into four transoms. The long pieces must be at least 20 feet long, and their distance apart a little less than the head diameter of the casks; the under edges are beveled to give them a good bearing on the casks. In default of square timber, spars may be used in the construction of the frame. The string pieces and transoms may be spiked or lashed, at their points of junction. The four exterior casks in the raft should be lashed to the frame, otherwise they may be carried off by the current when the raft lurches.

BRIDGES ON FIXED SUPPORTS.

The simplest form of military bridge is the one in which the stream is spanned by beams or balks resting upon the abutments. Assuming the load upon the bridge to be uniformly distributed, the greatest load in pounds which should ordinarily be placed upon a rectangular beam is given by the formula $W = 133\frac{bd^2}{s}$; in which b and d are respectively the breadth and depth of a balk in inches, and s is the span in feet. If the balks are circular, the formula becomes $W = 628\frac{r^3}{s}$; in which r is the radius in inches, and s is the span in feet. With ordinary material, if the balks are placed 2 feet from center to center, the limiting length of such bridges for army trains is 25 feet; this span requires balks 10 inches square, or 11 inches in diam-'er. If smaller balks are used, the interval between them 'liminished.

The bridge floor may be made of chess held in place by side-rails or spikes, but is usually made of saplings or poles covered with brush or hurdles, and earth. If the abutments are liable to be washed out by the action of the stream, they are protected by mattresses of brush, or by hurdles weighted down with stone. Hand-rails may be made of posts and poles, lashed or spiked together. The only difficulty in the construction of such a bridge is the placing of the balks over waterways and deep ravines; this may be done by using shears, a cart, or rollers as indicated in Pl. XXI, Figs. 83, 85, and 86.

Trestle Bridges.—If the stream cannot be spanned by the balks, one or more intermediate points of support may be formed of trestles. A *trestle* is a frame made of one or more horizontal *transoms*, and vertical or inclined *legs*, strengthened, if necessary, by *sway-bracing*.

Spar Trestles.—Pl. XXII, Fig. 93, shows the ordinary form of a spar trestle, in which AB and CD are the transoms, AC and BD the legs, and AD and BC the sway-braces. If the height of the upper transom above the ground does not exceed 12 feet, the size of square or circular legs may be determined by the formula $W = 300A$; in which W is the safe load and A is the area of cross-section in inches. The coefficient 300 is decreased by 10 for every foot of increase in height above 12 feet. The size of the upper transom is computed by the formula for the strength of a balk, assuming that the transom supports an entire bay. The flooring is constructed as in the single-span bridge described above. For a bridge 10 feet wide with 15-foot bays, the legs should be about 5 inches square.

In constructing a spar trestle bridge on land, the axis of the bridge is marked on the ground, and also the position of each trestle. If the span is short, the height of the upper transoms or the length of the legs of each trestle may be determined by stretching a cord along the axis of the bridge between the abutments and measuring the height of the cord at each trestle site; if the span is too

great for this method, a profile may be made of the depression between the abutments. If the ground is very irregular, the length of each leg must be determined by cords or profiles along each side of the bridge. In constructing a bridge over a stream, a similar method may be employed, by driving poles at the site of each trestle along the axis of the bridge, and measuring the height of the desired level of the upper transom above the water level and the bottom of the stream; or a profile of the bottom of the stream may be constructed from careful soundings. Having the width and height of each trestle, rough drawings of them may be made for the framing party. The different pieces are fastened together with lashings, with spikes, or with iron dogs. Trestles on land are easily erected by the use of pushing-poles and rope-guys, as employed in the erection of telegraph-poles. In the water they are sunk in place by employing a boat to carry them to the proper site, or by the use of two long poles as shown in Pl. XXII, Figs. 88 and 89. In Fig. 88, the outer ends of the poles rest upon the bottom, and the trestle is allowed to slide down them into place; it is then raised to an upright position by means of pushing-poles. In Fig. 89, the poles are used as cantilevers to support the trestle. The latter is pushed with poles along the cantilevers until it is over the proper site, and is then lowered into place by canting the supporting poles. In maneuvring the trestle, ropes are attached to the bottoms of the legs as indicated.

Two A frames of spars, or two tripods made of an A frame and a third leg, may be used instead of a trestle. The ends of the roadway bearers rest on the cross-pieces of A frames. Transportable tripods, with adjustable cross-pieces, are used in some foreign services.

Framed Trestles.—When square timbers or planks are available, a framed trestle may be constructed. In a framed trestle, the upper transom is fastened to, and rests on the tops of the legs and is called a *cap-sill*, the legs are fastened to, and rest on, the lower transom which is

called a *ground-sill*, or *mud-sill*. In erecting the trestle, the ground-sill is carefully leveled.

Pile Trestles.—In marshy ground the ordinary trestles settle unevenly ; it is preferable, in such sites, to construct pile trestles. A *pile trestle* or *bent* is simply a row of piles crowned by a cap-sill and strengthened by sway-bracing if necessary [Pl. XXII, Fig. 95]. If the piles are small they may be driven with mauls from a temporary platform [Pl. XXII, Fig. 94] ; if large, they are driven with a movable pile-driver, operated by man or steam-power. The former, called a *ringing engine*, is easily constructed in the field.

Crib Bridges.—The supports of a bridge may be cribs formed of rough logs halved into each other near their ends and fastened together with spikes or treenails. Cribs filled with stone form excellent supports in a stream with a rocky bottom and swift current. A low support for a viaduct may be formed of two rows of posts, placed a few feet apart and tied together with wire, to retain a pile of fence-rails, planks, or logs [Pl. XXII, Figs. 91 and 92].

Lock or Strut Bridges.—Where the abutments of a bridge are high and firm, and the span is not too great, lock or strut bridges may be constructed ; these consist of two frames, similar to the spar trestle, which form inclined struts for the support of the bridge. A single-lock bridge furnishes one intermediate support between the abutments, a double-lock bridge two, and a single-sling bridge three. A *single-lock bridge* is made up of two trestle-frames [Pl. XXII, Fig. 93], which rest on the abutments, below the roadway, and are so inclined that the frames cross each other below the level of the roadway ; the legs of each rest on the upper transoms of the other. A roadway-bearer rests upon the legs at their intersection. This type is suitable for spans of from 25 to 35 feet. In the *double-lock bridge* [Pl. XXI, Fig. 82], the two inclined trestle-frames do not cross each other, but are held apart by a horizontal strut. This strut is firmly fastened to the upper transoms, and supports two roadway-bearers. This

type is suitable for spans of 30 to 40 feet. The *single-sling bridge* is similar to the single-lock, but the frames cross each other several feet above the roadway. The upper transoms, at the level of the roadway, form two roadway-bearers, and a third is suspended from the cross, formed by lashing together the legs of the two frames. This type is suitable for spans of 40 to 50 feet.

Other Bridges.—The bridges described in this chapter are those that form part of the regular organization of an army, or can be readily constructed with the tools included in the equipment of all field troops and of the materials found on any site. In engineering manuals will be found descriptions of the more complicated truss and suspension bridges which are constructed by the engineers. In some foreign services a transportable steel truss has been adopted to replace any railway bridge which may be destroyed by an enemy.

CHAPTER XIV.

MILITARY DEMOLITIONS.

A military demolition is the destruction by an army of any object in the theater of war, whose preservation would be injurious to the army itself, or be useful to the enemy. Demolitions are employed in both defensive and offensive operations. In defensive operations they are employed in clearing the foreground, and in improving communications upon the battle-field; in destroying communications, fortifications, and munitions of war on a retreat; and in destroying, by means of raids, the lines of supply in rear of a pursuing enemy. In offensive operations, they are employed in destroying lines of communication or operation which may be useful to the enemy, or in destroying the resources of any portion of the enemy's base.

In our Civil War military demolitions were extensively employed on both sides to frustrate military movements. The most notable examples were the destruction of the Louisville & Nashville and Nashville & Chattanooga Railroads, in rear of the Army of the Cumberland, by the Confederate cavalry commanders Forrest and Morgan in 1862–63, thus interfering with the supply of the Union Army, and preventing any forward movement; the destruction of the resources of the Shenandoah Valley, Virginia, by General Sheridan in 1864, to prevent its future use as a line of operation by which the Confederate Army might invade the Northern States; the destruction of the railways in his rear, by General Sherman in his "March to the Sea," thus preventing pursuit, and also cutting the communications

between the Seaboard and Gulf States; and the complete destruction of the resources of that portion of the Confederate base of operations formed by the Gulf States east of the Mississippi, by General James H. Wilson in 1865.

Extensive demolitions on the offensive are usually effected by cavalry or cavalry pioneers, as in the Civil War; in modern European armies these troops are provided with tools and explosives for this purpose. Demolitions on the defensive are executed by the engineers, or infantry pioneers, who are especially equipped therefor.

Means of Destruction.—Intrenching tools, fire, and explosives, are the principal means of effecting demolitions. The particular means employed depends upon the size of the working party, the character of the object to be destroyed, and the length of time in which the work must be executed.

Explosives.—The requisites of an explosive for military purposes are safety, stability, and simplicity in use. Experience has shown that gunpowder, guncotton, picric-acid compounds, dynamite, and rackarock are the most suitable explosives for demolitions. The explosive compounds have the advantage over gunpowder of being more powerful and of requiring less careful tamping; in fact they may be employed without any tamping whatever, but the explosive effect is very much reduced.

Gunpowder.—If gunpowder is used the following points should be noted: the fine and quick-acting grades are the most powerful; the charge should be well tamped; numerous points of ignition are advisable in large charges; large detonating fuses are superior to other modes of ignition; the powder must always be kept dry. Charges of gunpowder are placed in water-tight bags or casks.

Guncotton.—Guncotton, moistened with 15 to 30 per cent of water, burns slowly if held in a flame or thrown into a fire; it cannot be ignited or exploded by percussion or friction; a rifle-ball tears it to pieces without igniting it; it may be handled, sawed, or cut, with safety; its chemical

organization is unaffected by frost. Although in the wet state it can only be detonated by an abnormally strong detonator, it can be detonated readily if a small primer of dry guncotton is placed in close contact with it. It may be safely stored and transported, if preserved from light. Dry guncotton burns readily, and in a confined place the temperature may rise to the point of detonation; it may be ignited by percussion, but a rifle-ball will only tear it to pieces, setting fire to the fragments. The poisonous fumes produced by the detonation of guncotton make it an undesirable explosive in mining or similar work.

Guncotton is the explosive adopted in the British service, where it is formed into *disks* of 1 and 1½ ounces, and into *slabs* of 1½ and 2 pounds. The disks, being used as primers, are kept dry and coated with beeswax; they are stored in hermetically sealed cylinders each containing 5 disks. The slabs are stored and carried into the field soaked with 20 to 30 per cent of water. They are packed in sealed tin boxes placed in an outer box of wood. Guncotton is not manufactured to any considerable extent in this country, and would not, at present, be available for military purposes.

Picric-acid Compounds.—In the form of melinite, this explosive is used in the French service; and in the form of "shell-filling c/88," it is used in the German service. It is claimed for these explosives that they are as safely handled as guncotton, and are more stable if kept from contact with lead, copper, and calcium. In the French service, melinite is formed into *cartridges* of 3⅓ ounces, and into *petards* of 5 ounces and 2 pounds. In the German service, shell-filling compound is formed into *disks* of 2⅓ ounces, *slabs* of 7 ounces, and *cartridges* of 2 pounds. The disks and slabs are protected from moisture by a paraffin coating, and are wrapped in paraffined paper. The cartridges are inclosed in a tin case. These explosives are not now manufactured in the United States.

Dynamite.—Dynamite, under ordinary conditions, may

be handled with safety, but is liable to give severe headache and nausea to persons unaccustomed to handling it. If the cartridges are kept in a damp place, or are exposed to the direct rays of the sun or to high heat, the nitro-glycerine exudes and the dynamite becomes exceedingly sensitive. If exposed to a temperature of about 40 degrees Fahrenheit, dynamite freezes and, although detonated with great difficulty, it becomes more sensitive to percussion and should never be used in this condition. It may be thawed by placing it in a warm room, but protected from the direct rays of the fire, or by placing the sticks in a double boiler similar to a glue-pot; the outer one contains warm water and the inner one the dry sticks of dynamite. Dynamite is more sensitive to percussion than the other explosives mentioned. It does not explode if exposed to a blow of wood upon wood; it may explode if exposed to a blow of stone upon stone, and will usually explode if exposed to a blow of metal upon metal, unless the metals be copper or lead. It is extensively manufactured in this country in several grades under the names of Atlas Powder, Giant Powder, Hercules Powder, etc., and is employed in blasting, mining, etc. The most powerful contains 75 per cent of nitro-glycerine and is called dynamite No. 1. It is usually found in the market in cylindrical cartridges 8 inches long, with diameters of $\frac{7}{8}$, $1\frac{1}{4}$, and 2 inches. The cylinders are wrapped in paraffined paper, and are packed in sawdust in wooden boxes containing fifty pounds each. Dynamite should be stored in a dry, well-ventilated place.

Rackarock.—This is an explosive formed by saturating a cartridge of potassium chlorate with mono-nitro-benzene. The two substances are separately non-explosive and may be transported without danger; the chlorate cartridges in boxes and the liquid benzene in cans. The liquid is poured over the cartridges just before using. Rackarock is found in the market in cylindrical cartridges similar to those of dynamite, and is preferred to other explosives by many

military engineers, on account of its safety in transportation and storage. It is somewhat more expensive than dynamite and requires a more powerful fuse. Like dynamite, it may be used under water.

Methods of Igniting Charges.—The ordinary method of igniting a charge of powder or high explosive is by means of a Bickford safety-fuse and detonator [Pl. XXIII, Fig. 96]. A *safety-fuse* is a train of powder inclosed in a flexible wrapping of hemp or cotton, which is made waterproof when used in damp situations or in submarine work. The usual rate of burning is about 3 feet per minute. An *instantaneous* fuse which burns at the rate of 30 yards per second is manufactured for use in producing simultaneous explosions. The various charges to be exploded are connected by equal lengths of instantaneous fuse spliced to the end of a piece of ordinary safety-fuse. A *detonator* is a cylindrical copper cap partially filled with fulminate of mercury. The end of the safety-fuse is cut square and made to fit the detonator by paring the coating or by wrapping it with paper. It is inserted in the detonator until it touches the fulminate, and is fastened there by crimping the copper tube, either with a special pair of pincers or with the back of a knife. The detonator is inserted in holes which are left for it in the slabs of guncotton and picric-acid compounds, but may equally well be tied to them. In the ordinary dynamite cartridge, the top of the cartridge is opened and a hole is carefully made with a wooden rod. The detonator is inserted in this hole, and the paraffined paper is drawn close around the safety-fuse and tied with a string [Pl. XXIII, Fig. 97]. To prevent the detonator from being torn out of the cartridge, the safety-fuse may be wrapped around it. If several cartridges in close contact are exploded, the detonator need only be placed in one. Detonators should never be stored or transported with high explosives.

For igniting gunpowder a train may also be made of a strong linen tube filled with powder; this is called a

powder-hose; the hose may be protected by inclosing it in a wooden trough, called a *hose-trough.*

Electricity may be employed in detonating high explosives, or in igniting gunpowder. For this purpose an *electric fuse* is used instead of the simple detonator. It consists of a tube A, fulminate charge B, fuse plug or cement C, insulated conductors D, and platinum bridge E [Pl. XXIII, Fig. 98]. Electric fuses, like detonators, must not be stored or transported with high explosives. Insulated wires connect the fuses with the generator; joints in these wires are made by baring the ends of the conductors and then twisting the wires together. At the generator the bared wires are inserted in the binding-posts. The *generator* usually employed in mining, blasting, and demolitions, is the Laflin-Rand Magneto-Exploder No. 3 [Pl. XXIII, Fig. 99]. It is a small portable dynamo inclosed in a box which measures $5 \times 8 \times 16$ inches; it weighs 18 pounds and may, under favorable circumstances, be used to explode ten fuses arranged in series.

Formulas.—The following empirical formulas are given in the Chatham course in military engineering. They were deduced from experiments made with guncotton, but will apply equally well to dynamite No. 1. If the weaker forms of dynamite are used the charges must be correspondingly increased.

The formulas are given for high explosives untamped; the charge may be decreased about one-half if well tamped. They may be used for well tamped gunpowder if the charge is doubled.

Timber.—$C = \frac{8}{3}T^2$, if the charge is placed in one or more holes bored in the same plane of cross-section.

$C = 3BT^2$, if the charge is arranged as a necklace, or laid across one side. C = charge in pounds, B = breadth in feet, T = thickness in feet.

The first formula was tried at West Point with 60 per cent dynamite and was found effective without tamping; better results were obtained, however, when the hole behind the

charge was tamped with clay. The second formula did not give sufficiently large charges with 60 per cent dynamite.

Wrought-iron Plates.—$C = \frac{8}{3}Bt^2$. C = charge in pounds, B = breadth in feet, t = thickness in inches. The cartridge must extend entirely across the plate.

Other authorities give the charge for I beams as $\frac{1}{8}$ of a pound per square inch of cross-section for small beams, and $\frac{3}{5}$ of a pound per square inch for large ones.

Masonry.—$C = \frac{4}{4}BT^2$, for brick arches; $C = \frac{1}{2}BT^2$, for brick walls. C = charge in pounds, B = length of breach in feet, T = thickness of wall in feet.

Field and Siege-guns.—From $1\frac{1}{2}$ to 4 pounds of explosive, placed in the bore and tamped with sand, will destroy a field or siege-gun.

Applications.—Trees may be felled by placing the charge in radial holes bored for the purpose, or by arranging the charge as a necklace around the tree if less than a foot in diameter [Pl. XXIII, Figs. 100 and 101]. Timbers may be treated in a similar manner, or the charge may be laid across one side [Pl. XXIII, Fig. 102]. During the Civil War a torpedo was devised for the destruction of wooden bridge timbers; it consisted of a bolt of $\frac{7}{8}$-inch iron, 8 inches long, with a head about 2 inches in diameter and 1 inch thick. A washer of the same size, with a fuse hole, was placed at the other end just inside the nut. Between the head and the washer was a tin cylinder $1\frac{3}{4}$ inches in diameter which was filled with gunpowder. The torpedo was inserted in a hole bored in the piece to be destroyed, and ignited by a safety-fuse. Stockades, palisades, etc., are destroyed in the same manner as trees; the charges are placed in holes bored in the timber, or are simply laid against the foot of the stockade or palisade and well tamped with earth.

Iron beams and girders, if small, are destroyed by placing the charge between the flanges; if large, by placing the charge entirely around the beam or girder [Pl. XXIII, Figs. 103 and 104]. A girder is difficult to destroy with

collisions or by running trains over embankments. Bridges and tunnels are usually destroyed by explosives as explained above. Long and high bridges and tunnels are the easiest parts of a railway to destroy, and are the most difficult parts to replace or repair. Around railway stations the frogs of switches are destroyed by explosives wedged between the rails.

In the Civil War, when it was desired to render a portion of track temporarily useless, a company, equipped with levers, was distributed in a line along a section of the track. The ties having been loosened and the fish-plates at the ends of a section removed, at a command the track was lifted up on one side and tipped over. Two men were usually detailed to each tie. To destroy the track permanently, the rails were afterwards loosened from the ties with sledge-hammers and crowbars, and the ties were collected in piles of 50 to 80, and burned. The rails were thrown upon the burning ties and, when red hot, were bent by loading their ends, or were twisted by using cant-hooks or by wrapping them around a tree or telegraph-post. Other methods of removing the rails from the ties were by means of a cant-hook and rope [Pl. XXIV, Fig. 107] invented by General Poe, Chief Engineer of General Sherman's army; or by a lever and rope [Pl. XXIV, Fig. 108] invented by General Haupt, engineer in charge of Military Railways during the Civil War. With the former, forty men could tear up and destroy four fifths of a mile of track in an hour.

Telegraph Line.—A telegraph line may be temporarily disabled by skilfully placing "faults" in it. These are breaks, leaks, and contacts. A *break* is a disconnection in a conductor; a *leak* is a ground connection attached to the conductor; a *contact* is a wire connecting two or more conductors. These should be so placed as to be concealed from any one casually examining the line. To destroy the line, the wires after being removed from the poles are twisted together, and the poles are cut down and burned.

CHAPTER XV.

ENCAMPMENTS AND COMMUNICATIONS.

ENCAMPMENTS.

When in the field, an army at rest may be lodged in cantonments, camps, or bivouacs. In *cantonments*, the troops are quartered on the inhabitants ; villages or towns are selected for the encampment, and the troops are apportioned among the habitable buildings. From a sanitary point of view this is the best form of encampment, but it can be utilized only in a densely populated country where it is sanctioned by custom. It is the ordinary form of encampment in Central Europe, but has never been employed in this country. If in the vicinity of the enemy, the village or town may be fortified as explained in Chapter XII.

In *camps*, troops are lodged in ordinary tents in warm weather, and in temporary huts in cold weather. In our own wars, troops were ordinarily lodged in camps during the period of mobilization and instruction, and during the winter months when active operations were suspended. The general considerations which should govern the selection and arrangement of such encampments are the health of the troops, and the convenience of supply and command. The *preservation of the health* of the troops demands a sanitary and ample site ; good cover, water-supply, and drainage ; and a thorough system of police. *Convenience of supply* necessitates a site near some railway or waterway, with ample switches, docks, and warehouses. *Convenience of command* requires the grouping of the units of the command in the vicinity of the headquarters of the combined

units. A winter or other encampment in the vicinity of the enemy is protected by a cordon of intrenched outposts.

Choice of Site.—A sanitary site is one from which the water is rapidly removed by percolation through the soil, by evaporation by the sun and winds, and by the natural drainage routes of the site. It must be sufficiently removed from marshes, old camps, and other unhealthful localities, to be unaffected by the noxious vapors which arise from them. Summer camps should be exposed to the prevailing winds; winter camps should be protected from them, by some intervening ridge or woods. Unhealthful sites are, therefore, sites whose soil is mostly clay, particularly if they are level; plowed fields; thick woods, or woods with much underbrush or low limbs; any low or marshy ground; and in the United States, sites with a northern exposure. For the comfort of troops, the tents should not be pitched near any regularly traveled road where the occupants will be disturbed by the noise and suffer from the dust. If it be absolutely essential to camp on a site more or less unhealthful, great care should be taken to comply with all the other conditions for preserving the health of the troops.

Extent of the Site.—An infantry regiment requires for camping purposes about one acre of ground for each one hundred men; a cavalry regiment requires about one-third more space than infantry; artillery requires for each complete six-gun battery a space equal to that occupied by one thousand infantry. The special arrangement of these camps is given in the drill regulations. A better form of infantry camp, especially for volunteers, is given in Pl. XXV, in which the kitchens are placed close to the officers' tents where they may be readily inspected, and the latrines are more distant from the camp. The depth of this camp may be decreased by placing the battalion commander's tents in the same line as those of the company officers. Wagon trains require about three acres for each twenty-five wagons, their teams, and teamsters. The space occupied

by the larger units, brigades, divisions, and corps, depends upon the topographical features of the site, and upon the convenience of supply. At Camp Meade, Pa., in 1898, the camp of the Second Army Corps, which was especially selected with a view to proper sanitation, covered an area of about four square miles. The dispersion of the units over this area was rendered necessary by numerous corn fields which were not suitable for regimental camps. This corps was composed almost wholly of infantry and numbered 35,000 men of whom about 22,000 were present. If there is an accurate topographical map of the site, the approximate location of the camps may be determined by making rectangles of cardboard, to the scale of the map, to represent regimental and battery camps; these may be placed upon the map and their position adjusted to the site.

Tents.—The tents used in our service are the wall, the common, the conical wall, and the hospital tent. The dimensions of the *wall tent* are approximately 9×9 feet; the *common*, 8½×7 feet; the *conical wall*, diameter 16½ feet; and the *hospital*, 14×14½ feet. The allowance of wall tents for a regiment is two for each field officer, one for each captain, staff officer, and regimental headquarters, and one for every two lieutenants of companies. The allowance of common tents is one for every three men, and one for each company's subsistence stores. Instead of common tents, the conical wall tents may be issued; seven to each company or troop, and nine to each light battery. For hospital use each regiment is allowed one common, and four hospital tents. The tents should all be provided with tent floors raised three or more inches above the ground so as to allow free circulation of air underneath. When practicable, charcoal or lime is strewn under each floor. After a prolonged rain storm the ground underneath the tent floor is liable to become saturated with moisture; to dry it the floor should be raised for a few hours on a warm, dry day.

Huts.—In camps which are to be occupied a considerable length of time, substantial huts replace the tents. These may be made of framework covered with boards, corrugated iron, painted canvas, tarred paper, strawboard, or thatch. The particular material used depends upon its availability. The essential point in the construction of huts is proper ventilation. This may be secured as indicated in Pl. XXIV, Fig. 113. In the winter camps of the Army of the Potomac, log huts were used [Pl. XXIV, Fig. 114]. Each hut had a wall of horizontal or vertical logs, properly chinked, three or more feet high; openings in the wall were left for a door and a fireplace. The roof was made by stretching one or more tents, or tent flies, over a skeleton frame composed of the ridge pole and a few rafters. A log chimney, usually crowned with a barrel, was constructed outside the gable end of the hut. A hut should be floored in the same manner as a tent; if this be impracticable, raised camp beds are constructed.

Water-supply.—The minimum daily amount of water desirable in a camp, is five gallons for each man, and ten gallons for each animal. In addition to this there should be a convenient bathing place for the men. As the water-supply of a camp has a very material effect upon the health and comfort of the troops, a thorough study of its quality, quantity, and method of distribution should be made before any site is adopted. Experience has shown that little reliance is to be placed on the ordinary methods of purification to remove the evils of an impure water-supply.

Quality.—The quality of water for drinking purposes can be safely ascertained only by chemical analysis; this is made by the officers of the medical department, and should be frequently repeated during the occupation of any site.

Quantity.—The method of determining the quantity depends upon the character of the source of the supply. An ordinary well is gauged by removing, by means of

pumps or otherwise, a convenient volume of water, and noting the time in which this volume is restored by the natural inflow. A small spring is gauged in a similar manner, after a barrel or length of sewer pipe has been sunk around it to act as a reservoir. The outlet of a large spring or a stream is gauged by constructing a wooden weir [Pl. XXIV, Fig. 115] in which the water escapes through a rectangular notch, cut in a thin board or sheet of metal, which is nailed to the back face of the weir. The approximate formula of discharge given by Trautwine is

$$d = 3.33(w - \tfrac{1}{5}h)\sqrt{h^3}.$$

d = discharge in cubic feet per second; w = width of notch (ef) in feet; h = head (ab) in feet. As $\frac{1}{5}h$ is usually very small, it may be omitted when approximate results only are required. To secure an even flow of water through the notch the depth of water under the notch, cd, should be at least twice the head, ab, and the width of the notch, ef, at least three times the head. The capacity of a pond is determined by gauging its outlet, and approximately determining the volume of water in it. The permanency of any water-supply may be determined by consulting the records, or by inquiries made of the inhabitants of the vicinity. If a site be otherwise satisfactory, its natural supply may often be increased by the construction of driven or artesian wells. A water famine, in one of the volunteer camps in 1898, was overcome by sinking an artesian well in the vicinity of the camp of each regiment.

Distribution.—If a well is the source of supply, the water is raised by means of pumps, and conducted in pipes or open conduits to a considerable distance from the source of supply, where it empties into tanks for the men, and into watering troughs for the animals. The well is inclosed by a fence of wire, or other material, to prevent its pollution. To facilitate the collection of the water of a spring, a number of barrels may be sunk along the outlet

close to the spring, so that the water fills them in succession. The spring is protected from surface water by ditches and embankments and is inclosed by a fence; the water is conveyed to tanks and troughs as described for a well. In a stream, a convenient place is indicated for the water-supply of the men, a second for the animals, and a third for the washing of clothes, etc. If the stream is a small one, dams with waste weirs are constructed at each of these places; the weirs are located in the solid ground at one end of each dam. Guards are placed above the upper dam to prevent pollution of the stream, and at each of the dams to regulate the use of the watering place. In large ponds or lakes, widely separated watering places are assigned to the men and animals; in small ones driven wells are sunk along the bank, and the water is conveyed to tanks and troughs placed far enough away from the pond to prevent its pollution. From the tanks the water is usually delivered to the different kitchens in barrels or water wagons. These, as well as the tanks, should be frequently cleaned with charcoal and boiling water to keep the water pure. If conveyed in open barrels through the camp, wooden floats should be placed over each barrel to protect the water from the dust. Camps that are to be occupied for a considerable time should have a regular system of water-supply, in which the water is conveyed in pipes from the source of the supply to the camp of each company, troop, or battery. At Camp Meade, Pa., a hydrant was placed at the end of each company street and a hut with three shower baths was constructed for every two companies over one of the natural drainage routes of the site.

Purification.—Water may contain, both in suspension and in solution, organic and mineral matter. Organic matter in suspension is killed by boiling; it is removed by filtration. Although boiling is the most effective way of destroying the life of germs, experience has shown that it is impracticable to wholly prevent the use of unboiled water by troops in the field. Mineral matter in suspension

may be precipitated by dissolving six grains of alum in each gallon of water, or it may be removed by filtration. Carbonate of lime in solution may be precipitated by adding to the water one-eighth its volume of lime-water, or by dissolving carbonate of soda in the water while it is boiling. Filters are used to remove both organic and mineral matter in suspension. The filtering material may be of porous stone, charcoal, or sand, or a combination of these materials. The Quartermaster's Department now issues filters to troops in the field, one to each company. The common forms of improvised camp filters used in the British service are shown in Pl. XXVI, Figs. 116 and 117. The charcoal is washed and dried before being placed in the filter; its purifying properties are destroyed after a short time, but may be renewed by exposure to the rays of the sun. The layer of charcoal is strongly compressed, so that the water passes slowly through it. When sand and gravel are used alone, the bed is about three feet thick, and is graduated from fine sand to coarse gravel. The rate of percolation should be about six inches per hour.

Drainage.—Surface drains are so constructed that no water can run under any tent or hut, into any latrine, or remain standing, until foul, either in the camp, or in its immediate vicinity. A small area about each water trough and each tank should be paved, to prevent the soil in the vicinity becoming saturated.

Police.—A thorough system of police, including the proper disposal of all camp refuse is essential to the preservation of the health of the troops. One of the principal causes of sickness, especially in camps of inexperienced soldiers, is the failure of regimental commanders to enforce the camp police regulations with respect to latrines, and the disposal of garbage. Latrines are constructed as far from the kitchen and water-supply as possible, on ground which cannot be flooded; they are made as deep as the ıture of the ground will permit; they are inclosed with

brush or canvas, and are covered with a roof of canvas or boards. [Pl. XXVI, Fig. 122.] In each latrine there should be a small shovel for the use of each individual in covering the deposits with earth or disinfectants. The failure to comply with any of these simple suggestions is almost certain to lead to disease. A latrine should be abandoned in time to allow a surface filling of two feet of earth. The refuse of the kitchen is deposited in deep pits which are dug in its immediate vicinity, and is also covered with earth or disinfectants. The tents and camp grounds are thoroughly policed daily, and all garbage which can be burned is at once destroyed by fire. Camps which are to be occupied for any length of time should be provided with portable crematories for burning the refuse, and deposits in latrines should be removed daily by one of the odorless methods.

Warehouses and Sidings.—These should be ample and well arranged, so that there may be no delay, either in receiving and issuing supplies, or in loading and unloading troops. If practicable, store-houses with separate sidings should be constructed for each supply department, and sidings with suitable loading platforms for the troops and animals.

Convenience of Command and Supply.—In our army the brigade is made the unit of supply; the regiments of a brigade should therefore be separated no more than health and topographical features require. If the headquarters of a brigade be connected by telephone with the headquarters of the higher units, orders can be rapidly transmitted to the entire command. The headquarters of such units as are not brigaded should be connected with those of the division or corps to which they are assigned.

Bivouacs.—In bivouacs troops are lodged in shelter-tents, or under such covers as may be constructed of brush, straw, or other materials, found upon the site. Troops are in bivouac during active operations, and usually occupy the same site only a short time. The general considerations

which govern the selection and arrangement of a bivouac are *readiness for tactical movement*, and the *health of the troops*. In the vicinity of the enemy the first condition governs the arrangement; at a distance from him, the second. Readiness for tactical movements necessitates camping in order of battle, with intervals between the bivouacs of the tactical units, approximately as laid down in the drill regulations. If the troops bivouac in two or more lines, the distance between the lines is great enough to allow for latrines, unless these can be placed upon the flanks. If a line of defense is selected, the troops bivouac in the rear of this line so that they may reach it after a short march to the front. The bivouac should if possible be concealed from the enemy. The requirements for health and comfort of the troops are the same as those mentioned under camps.

In active operations, there is generally little choice offered in the selection of sites for bivouacs, as strategical considerations determine the lines of operation. The essential requisites of water and fuel for foot troops, and in addition forage for mounted troops and trains, usually fix the site. If the site be unhealthful, the troops remain upon it as short a time as possible, and guard against its dangers. Shelter-tents are ditched, and floored with boughs, mats of straw, etc. [Pl. XXVI, Fig. 121] to protect the men from the moisture of the earth. In the absence of tents, shelters are made of brush, straw, etc., for the protection of the men in camp and on outpost duty. [Pl. XXVI, Figs. 118, 119, 120]. If a bivouac is occupied for any length of time, the tents should be struck occasionally so that the ground under each tent may be thoroughly policed and dried. Fires for cooking are built in trenches constructed parallel to the direction of the wind [Pl. XXVI, Figs. 123 and 124]. If the camp is occupied for a considerable time, a rough chimney is constructed at one end of the trench and the trench covered over with slabs of stone, sheets of iron, etc., so as to produce a better

draft; a chimney may also be constructed at the center of a number of radiating trenches and the fire built in the one which is in the line of the wind. While thorough policing is usually impracticable in temporary bivouacs, rules relating to the care of latrines and the disposal of kitchen garbage must be strictly enforced, if large commands remain in bivouacs only a single day.

COMMUNICATIONS.

In modern warfare railways and water transportation are relied upon to mobilize an army, to transport it to the theater of operations, and to bring its supplies from the base of operations to the secondary depots immediately in the rear of the army. The movement of the army in the theater of operations, and the transportation of its supplies from the railway and river depots to the different commands, are over the ordinary roads of the country, supplemented by such others as the army may have time to construct.

The general study of the communications in any proposed theater of operations belongs to the domain of strategy; the care and improvement of the railways are usually the province of a special branch of the Engineer Department, but all officers must, to a certain extent at least, be responsible that the condition of the roads over which they are to march their troops shall not cause unnecessary delays in military movements. In our army in the Civil War, the duty of repairing the roads fell upon the pioneer detachments which were organized in every brigade and division of infantry in the Army of the Potomac, and in every army corps in the western armies.

Classes.—Roads may be roughly classed into paved, macadamized, gravel, and earth roads. A good paved road has a wearing surface of stone, brick, wood, asphalt, etc., and a foundation of concrete. A macadamized road has a wearing surface of small broken stone covered with

stone dust, gravel, or clay, and a foundation of larger broken stone either thrown in at random, or set on edge. A gravel road has a wearing surface of small gravel, and a foundation of coarse gravel. An earthen road has no distinct wearing surface or foundation; it is made by throwing up a slight embankment of soil and compressing it by travel.

Requisites of a Good Roadway.—The wearing surface should be smooth, hard, and impenetrable to water; the foundation should be firm and unyielding, so as to carry the travel without allowing any deformation in the wearing surface; the drainage should be such as to allow no water to remain upon the wearing surface, or in contact with the foundation or its bed.

Repairs.—The maintenance of a roadway in good condition demands that proper attention be given to its wearing surface, its foundation, and its drainage. The repairs of a road may be confined to its wearing surface, its foundation, its drainage, or to a combination of these elements. Existing paved and macadamized roadways require little attention from the military authorities. It is occasionally necessary to replace some of the culverts and bridges which have been destroyed by the enemy, or to strengthen others which are too weak to carry siege artillery and heavy supply wagons. A gravel road is in good order if it is properly drained, and if it consists of a bed of good gravel at least eight inches thick. If the gravel contains too large a percentage of clay, it will be in good condition during dry weather, but will be almost impassable in continuous wet weather. Particular attention must be paid to the thorough drainage of such a road, and in wet weather repairs must be made with gravel containing sand, or with clean gravel from a river bed. If no sandy gravel is obtainable, brush is carefully placed on the road to protect it from the formation of ruts. If the gravel used in the construction of a road is entirely free from clay or loam, the road becomes loose and wears

away rapidly in dry weather. It may then be improved by a thin coating of gravel containing clay or loam. Earth roads are similar to gravel roads, but deteriorate more rapidly under unfavorable conditions. If the soil is clay, every precaution should be taken to drain the road thoroughly, otherwise it will soon wear into deep ruts. In wet weather it should never be repaired by adding material containing clay, but always by material containing sand. If the roadway is naturally sandy, thorough drainage is not so essential, but in dry weather a little loam should be added to bind the sandy particles.

Drainage.—All overhanging trees and brush which prevent the rays of the sun from reaching the roadway are removed. The cross-section of the wearing surface is made the arc of a circle or two planes connected by the arc of a circle, and the crowning of the road is increased with the softness of the material in this surface; this prevents water remaining upon the roadway. Side ditches, cross drains, and culverts, are provided to carry off rapidly all surface and sub-soil water, so as to keep the soil upon which the road is constructed as dry as possible. The *side ditches* are open trapezoidal ditches two or three feet deep, which are usually constructed on both sides, just outside of, and parallel to, the roadway. Roads constructed along the slope of a hill have but a single ditch, which is on the side next to the hill; the surface of the road slopes from the outside towards this ditch. In a cut, unless the side slopes are protected by revetments, the side ditches are rendered useless by the crumbling slopes which rapidly fill them with soil; to obviate this defect use is made of blind drains. A *blind drain* is a small culvert covered with material which allows the water to percolate through it readily. The drain may be made of tile with open joints, of two or more longitudinal logs or fascines, or of rows of stone, covered with brush or broken stone. [Pl. XXIV, Figs. 109 and 110.] If the sub-soil is very wet, one or more such blind drains may be constructed under the roadway itself, either parallel

to the side drains or oblique to them. [Pl. XXIV, Fig. 111.] *Cross-drains* are especially essential in roads running along the face of a hill [Pl. XXIV, Fig. 112]; they may be shallow paved gutters, blind drains, or open culverts, depending upon the amount of water they are to carry, and the difficulty of making excavations. The first two forms are also useful in catching the water which flows in the wheel tracks down long steep slopes. *Culverts* are usually made of sewer or iron pipe, of planks, of logs, or of rough stone masonry. The minimum cross-section of a culvert of planks, logs, or stone is usually two feet square. A culvert should never be constructed in a new embankment, but should be located in the solid ground either at the bottom, or in one of the slopes of the depression in which it is constructed.

In swampy regions it is frequently impossible to drain the roads; in such localities an ordinary road is repaired by converting it into a corduroy or plank road. During the Civil War *corduroy roads* were made by laying a foundation of longitudinal stringers with intervals of four feet. These were covered with poles averaging seven inches in diameter which were placed in close contact. The wearing surface was made by filling the interstices with small sticks, and covering the whole with brush and earth. In many instances the covering of brush and earth was omitted, and the cross-pieces were held in place by side rails spiked to them. *Plank roads* are made of thick planks either spiked to the stringers or held in place by side rails. The planks replace the round sticks in ordinary corduroy construction. Wherever the road is wholly or partially below the adjacent ground, a ditch should be cut at some distance from, and parallel to, the road, to catch the surface water before it reaches the road. [Pl. XXIV, Fig. 112.]

Embankments.—In repairing roads in a mountainous region it is often necessary to construct retaining walls to support the road. These are usually made of dry stone

masonry with a batter $\frac{1}{5}$, or of logs in the form of crib-work. [Pl. XXIV, Fig. 112.]

New Roads.—New roads, constructed by troops in the field, must be made with a minimum expenditure of time and labor; these requirements forbid any extensive grading. Since the maximum grade on a road should, if possible, never exceed six per cent, or six feet in one hundred, a route must be selected on which this maximum grade can be secured without much labor. A reconnaissance with a hand level will usually determine the route. The road is located on the ground by driving pegs or stakes every one hundred or two hundred feet, to indicate the middle line. As soon as the location is fixed working parties begin to clear the roadway of trees, brush, and boulders, and to construct bridges and culverts wherever necessary. The road is then brought to grade, and is completed by giving it proper drainage, and a wearing surface of the best material which can be found in the vicinity.

APPENDIX A.

TABLE INDICATING THE NUMBER OF MEN, TOOLS, AND TIME NEEDED FOR EXECUTING FIELD FORTIFICATIONS.

Classification.	Number of Men in Working Party.	Hours.	Average Task per Hour per Day's Work	Tools.	Material.	Remarks.
Brush (bundles).	8	1	8	8 bill-hooks or hatchets	Brush, 1″ to 2″ at butt	Weight of bundle, 50 lbs. each.
Fascines.....	6	1	1	1 trestle, 1 fascine-choker, 3 bill-hooks, 1 hatchet, 1 hand-saw, 1 pair pincers, 1 measuring-rod, 1 mallet.	Per fascine. 3 bundles of poles, 12 binding withes or wires,	Poles about 2″ at butt. Weight of fascine, 150 lbs.
Gabions (brush).....	6	1	1	2 gabion-forms, 2 hatchets, 2 bill-hooks, 2 pair pincers, 2 measuring-rods, 2 lashings 5 ft. long, 2 hand-saws, 2 mallets.	Per gabion, 1 bundle-brush, 9 stakes, 9 binding withes or wires,	Weight of gabion, 36–56 lbs.
Gabions (wrought-iron)..	3	1	1	1 riveting-hammer, 1 cold chisel.	Per gabion, 10 stakes, 220 ft. hoop-iron, 70 rivets.	
Hurdles.....	3	2½	1	2 hatchets, 2 bill-hooks, 1 mallet, 1 hand-saw, 1 measuring-rod.	Per bundle, 1 bundle-brush, 10 stakes,	Hurdles are 6 ft. long, wt. 56 lbs.
Palisades (making panels)	24	1	7	5 axes, 4 hand-saws, 4 hatchets.	Per panel, 4 posts, 9 lin. ft. of 2″ planks, 1¾ lbs. 6″ spikes.	4 axe-men; 12 carriers; 4 men to saw and sharpen; 4 men to make and pile panels; 4 posts and 2 cleats to each panel, 4″ to 7″ diameter.
Pickets.	1	1	25	1 hatchet.		25 in one bundle.
Stakes.....	10–12	1	100–150	2 axes, 4 hatchets, 3 hand-saws, 1 measuring-rod.		2″–3″ at butt, 6 ft. long.

Classification.	Number of Men in Working Party.	Hours.	Average Task per Hour for Day's Work	Tools.	Material.	Remarks.
Trees (cutting up)	2	1	12″–6″ or 6″–12″	2 axes, 1 cross-cut saw, 1 measuring-rod.		
Trees (felling)	2	1	do.	2 axes, 1 cross-cut saw.		
Wire (anchoring ties)	2	1	60	wire-cutter or hatchet.	160 yards wire, ½″ to ¾″ diameter.	Telegraph wire.
Withes (anchoring)	2	1	12	2 bill-hooks,	do.	
Withes (binding)	1	1	12	1 bill-hook,		
EXCAVATION.						
Earth excavation	1	1	1 cu. yd.	1 spade,	Light soil,	1-hour tasks.
" "	1	1	¾ " "	1 spade, 1 pick,	Medium soil,	
" "	1	1	½ " "	do.	Hard soil.	
" "	1	1	¾ " "	1 spade,	Light soil,	Average of 4-hour tasks.
" "	1	1	½ " "	1 spade, 1 pick,	Medium soil,	
" "	1	1	¼ " "	do.	Hard soil.	
NUMBER OF MEN, TOOLS, AND TIME REQUIRED TO EXCAVATE 1 LINEAR YARD OF SHELTER-TRENCH.						
Shelter-trench, Pl. I, Fig. 1	1	½	1 lin. yd.	1 spade,		
" " Pl. I, Fig. 2	1	⅝	1 " "	1 spade, 1 pick,		
" " Pl. I, Fig. 3	1	1⅛	1 " "	1 shovel, 1 pick,		
" " Pl. I, Fig. 4	1	4	1 " "	1 shovel, 1 pick,		
" " Pl. I, Fig. 5	1	3 7/12	1 " "	1 shovel, 1 pick.		
" " Pl. I, Fig. 6	2	4	1 " "	2 shovels, 2 picks.		
" " Pl. II, Fig. 8.	8	8	1 " "	6 shovels, 2 picks.		

APPENDIX A.—*Continued.*

OBSTACLES.

Classification.	Number of Men in Working Party.	Hours.	Average Task per Hour per Day's Work	Tools.	Materials.	Remarks.
Abatis	18	1	1 linear yd. in 3 rows,	2 axes, 2 hand-saws, 2 cross-cut saws, 2 picks, 4 spades, 2 mauls,		3 squads.
Entanglements (low wire)	10	1	9 linear yds	2 mauls, 4 wire-cutters, 4 picks, 4 hatchets. 1 measuring-rod,	Per linear yard, 1⅜ stakes. 28 yards wire,	10 yards wide.
Entanglements (high wire)	10	1	3 linear yds.	2 mauls, 4 wire-cutters, 4 picks, 4 hatchets, 1 measuring-rod,	Per linear yard, 2 stakes, 84 yards wire,	10 yards wide; without barbed horizontals and stakes placed in advance.
Entanglements (high wire)	10	1	1½ lin. yds.	2 mauls, 4 wire-cutters, 4 picks. 4 hatchets, 1 measuring-rod,	Per linear yard, 2 stakes, 92 yards wire,	10 yards wide, with barbed horizontals and stakes placed in advance.
Palisades (erecting panels)	10	1	6	4 spades, 2 picks, 2 rammers,	6 panels,	4 men can carry panel; 6 panels = load for 4-horse team; distance = 50 yards.
Pickets (small)	10	1	2 sq. yds.	3 hatchets, 2 hand-saws, 2 garden-trowels, 2 mauls,	Per square yard, 9 pickets,	
Slashings	10	1	3 linear yds.	8 axes, 2 cross-cut saws,		4 rows deep.
Trous-de-loup	10	1	1 linear yd.	4 spades, 2 picks, 2 hand-saws, 2 hatchets, 1 maul,	50 stakes,	7 rows.

APPENDIX A.—*Continued.*

REVETMENTS.

Classification.	Number of Men in Working Party.	Hours.	Average Task per Hour per Day's Work	Tools.	Materials.	Remarks.
Brush	6	1	3 sq. yds.	2 axes, 2 spades, 2 hatchets, 1 maul, 1 cross-cut saw, 2 bill-hooks, 1 pair pincers,	Per linear yard, 3 stakes, 1 anchoring-wire, Per square yard, 1½ bundles brush	
Fascine (putting in place)	6	1	3 sq. yds.	2 spades, 2 hatchets, 1 mallet, 1 pair pincers,	Per square yard, 7 pickets, 3 anch'ing-stakes 3 anch'ing-wires,	
Gabion	4	1	15 sq. yds.	2 shovels, 1 pick,		Without anchorages.
Hurdle	6	1	5 sq. yds.	2 spades, 2 hatchets, 1 pair pincers, 1 maul,	Per 5 sq. yds., 3 hurdles, 9 stakes, 9 anch'ing wires,	Hurdles previously constructed.
Plank	6	1	4 sq. yds.	2 axes, 2 hatchets, 2 hand-saws, 1 maul, 2 spades,	Per square yard, 10 ft. B. M. planks 1 post, 1 anchor,	
Sand-bags (filling)	6	1	160	2 shovels, 1 pick,	160 bags,	
Sand-bags (placing in revetment).	2	1	160			100 square feet revetment.
Sod (cutting)	3	1	160	1 spade, 1 line,		Sods 18″ x 8″ x 4″ = 3 sq. yds.
Sod (placing in revetment)	3	1	3 sq. yds.	Pegs,	160 sods.	

APPENDIX B.

PENETRATION OF .30 CALIBRE RIFLE BULLET IN VARIOUS SUBSTANCES AT 500 YARDS RANGE, FRANKFORD ARSENAL, 1894.

(In tests with oak and pine the penetrations were in all cases transverse to the fibres.)

Material.	Penetration (inches).	Mean Penetration (corrected; inches).	Remarks.
Oak, green, not of best quality.	4 inches oak and 7 one-inch boards of pine butt; 4 inches oak and 4 one-inch boards of pine butt; 4 inches oak and 7 one-inch boards of pine butt; 6 inches oak and 4 one-inch boards of pine butt; 6 inches oak, point through oak 0.25 inches; 6 inches oak, point through oak 0.125 inches.		
	6.5 inches oak.....	Oak, 6.5	Penetration in 12-inch block.
	6.5 inches oak.....		
	6.5 inches oak.....		
Pine, soft, "white," "green," not of best quality.	16 inches solid pine block and 3.25 one-inch boards of pine butt; 16 inches solid pine block and 3.25 one-inch boards of pine butt; 16 inches solid pine block and 2.25 one-inch boards of pine butt; 20 inches solid pine block, point projected 0.5 inch; 18 inches solid pine block 20 inches in thickness; 18.5 inches solid pine block 20 inches in thickness.		
	21.6 21.8 21.6	21.66	Through one block 20 inches in thickness and into second block in close contact. In the latter penetrations (21.66 inches) the blocks were greener and contained more moisture than was the case in the experiments with pine blocks first recorded.
Brick wall 9 in. thick, 25 by 21.5 inches.	1.25 1.375 1.375 4.+	1.33	This section was made double of "dark strecher" or ordinary building-bricks. The wall was allowed to dry after laying for a period of about two weeks, but in examination made after firing to determine the effects, the mortar was found to be still somewhat "green" and soft. Struck joint and passed through to brick in rear. The bricks struck were cracked and shattered about the point of striking, triangular pieces being broken out, which allowed the bullets to change direction and pass into the joints. A concentrated and well-directed fire

APPENDIX B.—*Continued.*

PENETRATION OF .30 CALIBRE RIFLE BULLET IN VARIOUS SUBSTANCES AT 500 YARDS RANGE, FRANKFORD ARSENAL, 1894.

(In tests with oak and pine the penetrations were in all cases transverse to the fibres.)

Material.	Penetration (inches).	Mean Penetration (corrected; inches).	Remarks.
Brick wall 9 in. thick, 25 by 21.5 inches.	1.25 1.375 1.375 4.+	1.33	would probably soon make an opening through a wall so constructed. The bullets were found, as a rule, in the joints, but the last was apparently the only one that struck a joint fairly.
Sand, moist....	18.0 18.0 18.0	18.5	In obtaining penetrations in the different kinds of earth, the pine butts were placed in position in rear to provide for cases of complete perforation of the earth, but in all cases it happened that the thickness of the latter was sufficient to arrest the bullet. Additional tests will be made in accordance with your directions, as opportunity offers, to obtain a record of these mixed penetrations.
Loam.....	22.0 22.0 25.0	23.64	
Coarse gravel..	12.0 12.0 11.0 11.0	11.8	
Sand and loam, one-half each	17.0 17.0 21.0	18.8	
Clay.....	22.0 22.0 22.0	22.6	
Clay and loam, one-half each	22.0 22.0 22.0	22.6	*Report of Chief of Ordnance*, 1895.

In the case of sand, clay, etc., increase of one thirty-sixth is made as "correction" to allow for the half-inch pine board used to retain above. This correction is based upon the penetration at 500 yards of 18 one-inch pine boards, these being separated by spaces of one inch. The sand, clay, etc., were placed in a trough having a cross-section about 2 feet square, and allowed to settle simply by the pressure of their own weight.

PENETRATION OF .30-CALIBER RIFLE BULLET IN VARIOUS SUBSTANCES AT 53 FEET, AND THE PENETRATION OF .30-CALIBER RIFLE BULLET, THE .30-CALIBER CARBINE BULLET, AND THE .45-CALIBER SPRINGFIELD RIFLE BULLET IN PINE, AT 500 AND 1000 YARDS. SPRINGFIELD ARMORY, 1897.

(*Report of Chief of Ordnance, 1897.*)

At 53 feet range, the effect of the .30-caliber magazine rifle was as follows:

Iron boiler plate, 0.4 inch thick, backed. Penetrated.

Iron boiler plate, 0.468 inch thick. Penetrated.

Same plate, backed. Penetrated 0.46 inch and bulged plate at back.

Iron boiler plate, 0.566 inch thick, backed. Penetrated 0.255 inch.

Soft steel plate, 0.2 inch thick, backed. Penetrated.

Seasoned oak across grain, exceptionally hard and tough. Penetrated 20.7 inches.

White pine target of 1-inch boards, spaced 1 inch apart. Penetrated 45.8 inches of pine.

At 500 yards range, in the same target, the penetration for the .30-caliber rifle was 19.85 inches of pine; for the .30-caliber carbine, 17.96 inches; and for the .45-caliber Springfield rifle (lead bullet, 500 grains) 12.85 inches.

At 1000 yards range, in the same target, the penetrations in pine were: .30-caliber rifle, 11.44 inches; .30-caliber carbine, 11.22 inches; and .45-caliber Springfield, 8.44 inches.

THICKNESS OF FIELD SHELTERS.

(INSTRUCTIONS FOR THE GERMAN ARMY.)

AGAINST RIFLE FIRE.

Sand 75 cm.
Ordinary earth 1 m.
Loose sod or turf and loam 2 m.
Packed snow 2 m.
Grain sheaves 5 m.
Soft wood 1 m.
Oak wood 60 cm.
Steel plate 2 cm.
Brick wall 50 cm.
Pine boards inclosing 20 cm. of broken stone.

AGAINST FIELD ARTILLERY.

Direct fire, Single shots, " " { earth 1 to 2 m. masonry 1 m. snow about 8 m.

Shell and shrapnel, earth 40 cm. to 1 m.
" " " wood as splinter-proof 5 cm.

AGAINST SIEGE ARTILLERY.

Direct fire, single shots, earth 3 to 4 m.
Shell and shrapnel, earth 1 m.
" " " wood as splinter-proof 10 cm.

1 m. = 39.4 inches = $1\frac{1}{3}$ feet approximately.
1 cm. = 0.4 inch approximately.

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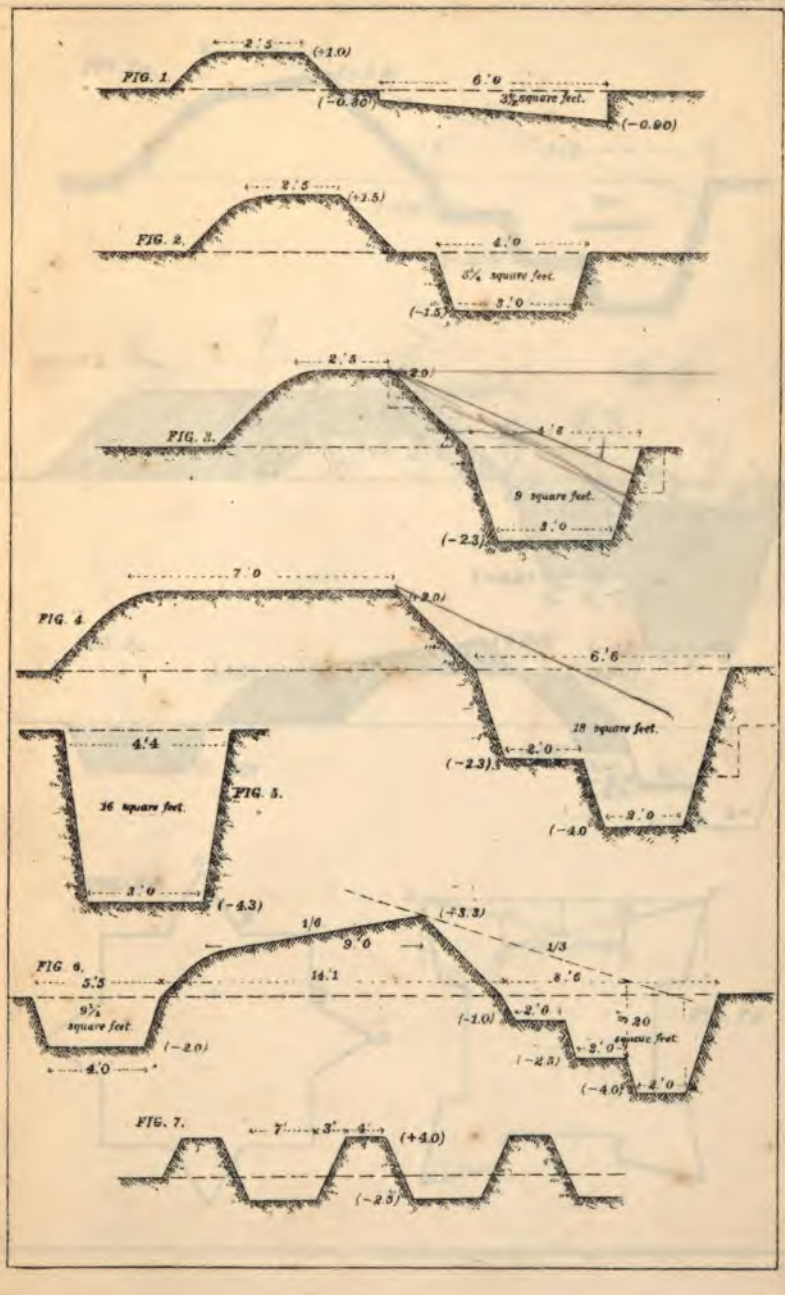


FIG. 1.
2'5
(+1.0)
6'0
3½ square feet.
(−0.30)
(−0.90)
FIG. 2.
2'5
(+1.5)
4'0
8¼ square feet.
3'0
(−1.5)
FIG. 3.
2'5
2.0
4'8
9 square feet.
3'0
(−2.3)
FIG. 4.
7'0
2.0
6'6
18 square feet.
2'0
(−2.3)
2'0
(−4.0)
FIG. 5.
4'4
16 square feet.
3'0
(−4.3)
FIG. 6.
1/6
9'0
(+3.3)
1/3
5'5
14'1
8'6
9½ square feet.
(−2.0)
4'0
(−1.0)
2'0
3.0
square feet.
3'0
(−2.3)
2'0
(−4.0)
FIG. 7.
7'
3'
4'
(+4.0)
(−2.3)

PLATE I A

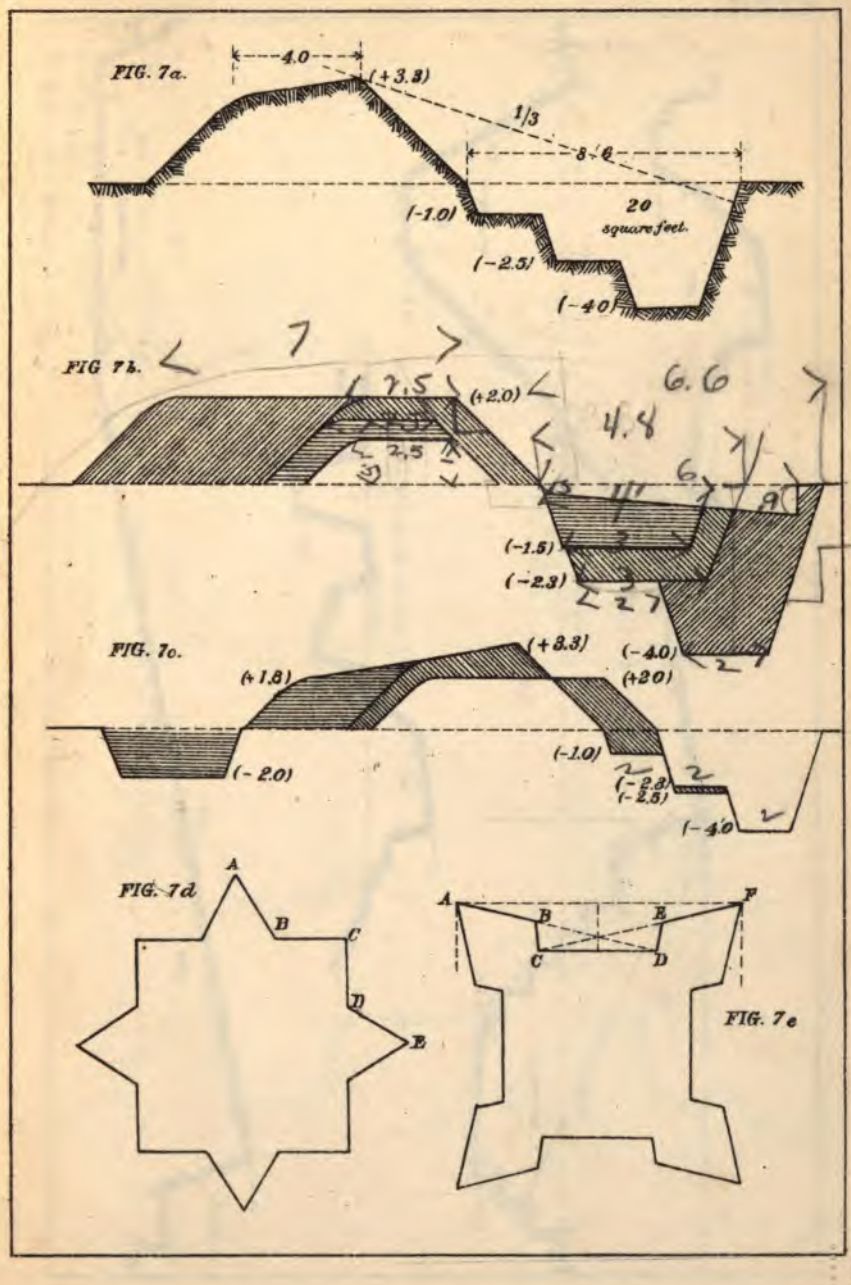


FIG. 7a.
4.0
(+3.3)
1/3
8.6
(-1.0)
20
square feet.
(-2.5)
(-4.0)
FIG 7b.
7
7.5
(+2.0)
6.6
4.8
2.5
6
9
(-1.5)
(-2.3)
FIG. 7c.
(+3.3)
(-4.0)
(+1.8)
(+2.0)
(-1.0)
(-2.8)
(-2.5)
(-2.0)
(-4.0)
FIG. 7d
A
B
C
D
E
A
B
E
F
C
D
FIG. 7e

PLATE II

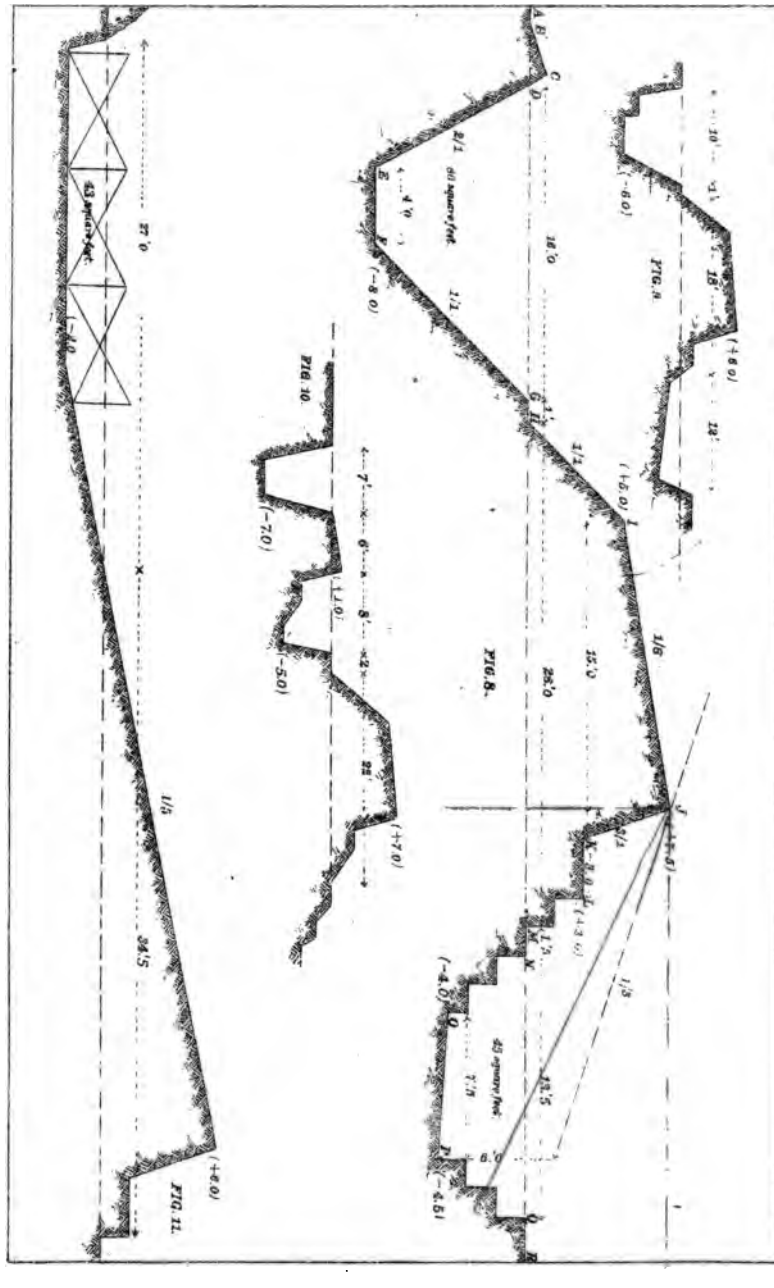


FIG. 8.
FIG. 9.
FIG. 10.
FIG. 11.
60 square feet.
45 square feet.
43 square feet.

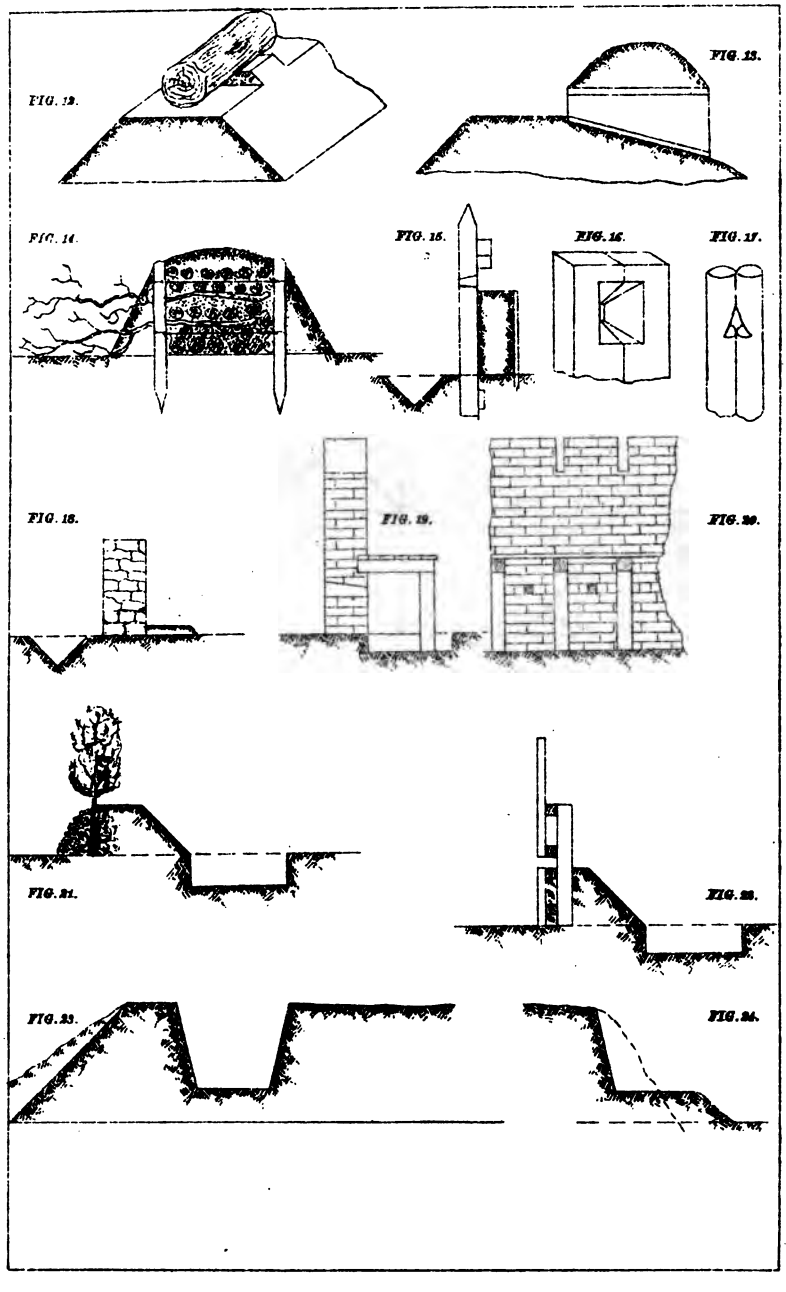


FIG. 13.
FIG. 13.
FIG. 14.
FIG. 15.
FIG. 16.
FIG. 17.
FIG. 18.
FIG. 19.
FIG. 20.
FIG. 21.
FIG. 22.
FIG. 23.
FIG. 24.

FIG. 25.

FIG. 26.

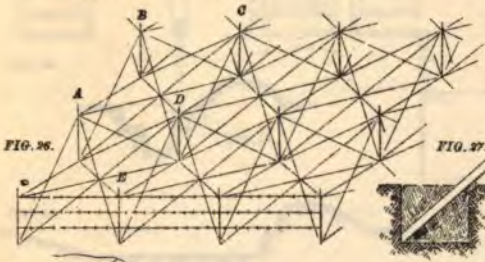


FIG. 27.

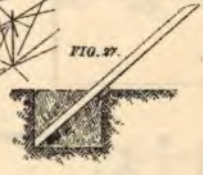


FIG. 28.

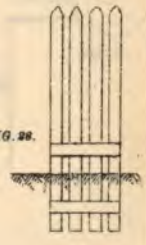


FIG. 29.

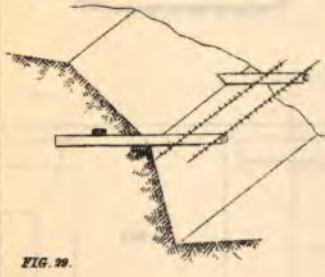


FIG. 30.

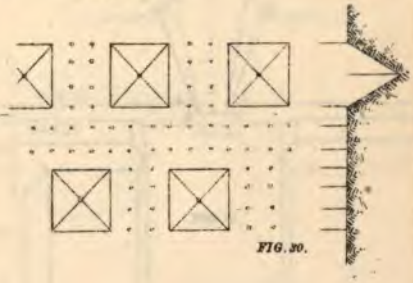


FIG. 31.

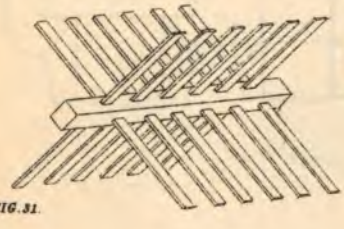
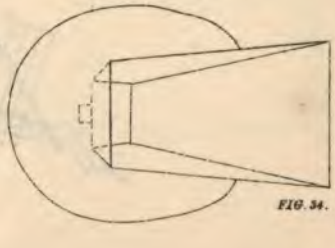
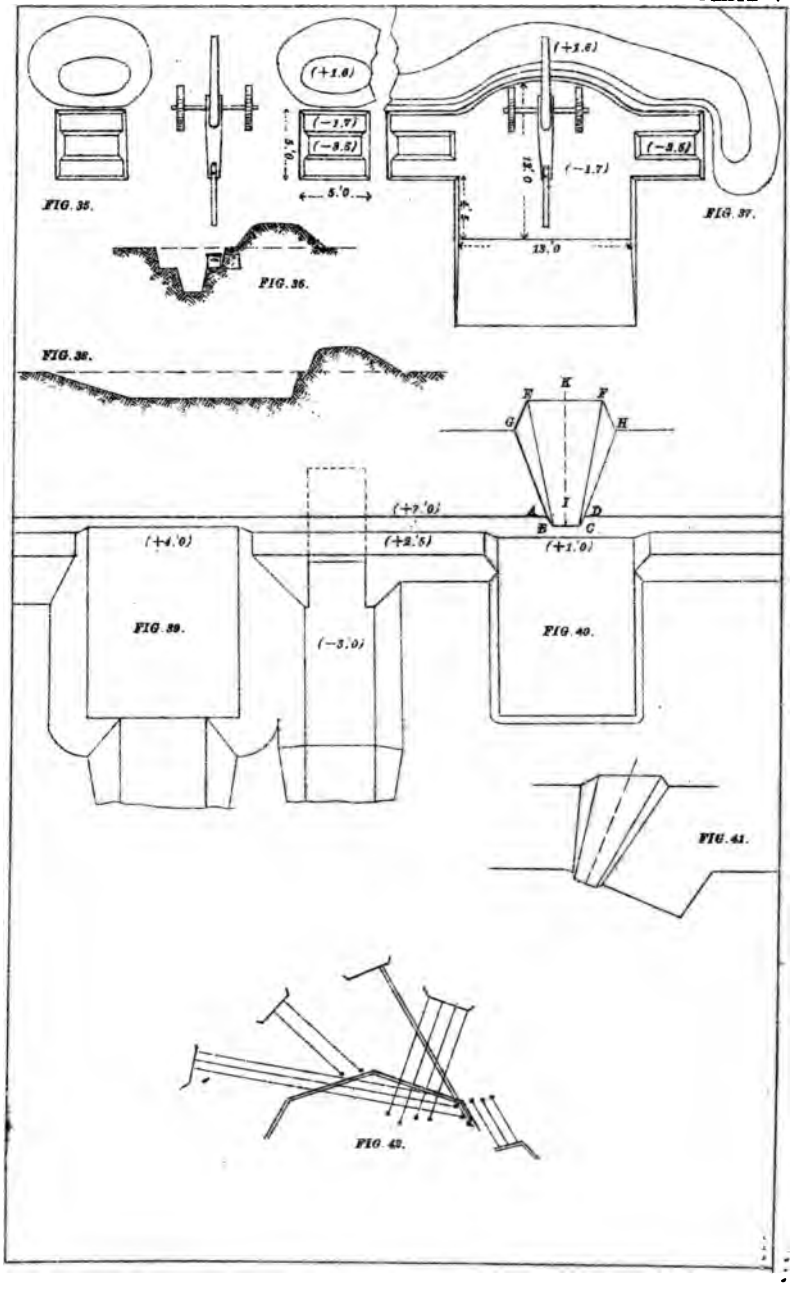


FIG. 32.

FIG. 33.

FIG. 34.




(+1.6)
(−1.7)
(−3.5)
5.'0
5.'0
FIG. 35.
FIG. 36.
(+1.6)
(−1.7)
(−3.5)
13.'0
FIG. 37.
FIG. 38.
E
K
F
G
H
I
A
D
B
C
(+7.'0)
(+2.'5)
(+1.'0)
(+4.'0)
FIG. 39.
(−3.'0)
FIG. 40.
FIG. 41.
FIG. 42.

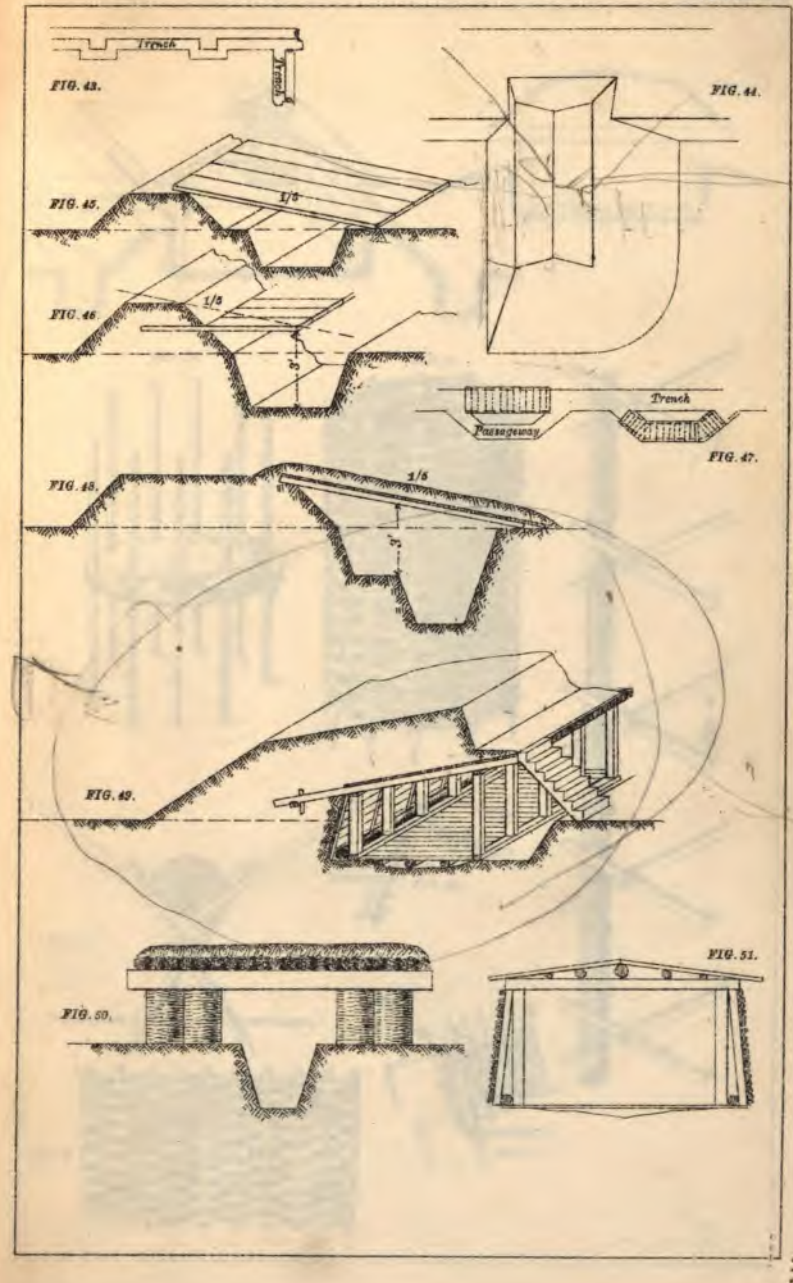

Trench
Trench
FIG. 43.
FIG. 44.
FIG. 45.
1/5
FIG. 46.
1/5
3'
Trench
Passageway
FIG. 47.
FIG. 48.
1/5
3'
FIG. 49.
FIG. 50.
FIG. 51.

FIG. 52.

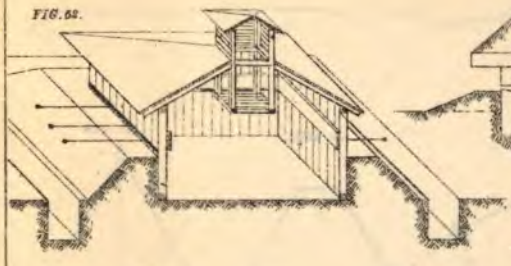


FIG. 53.

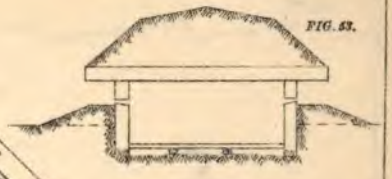


FIG. 54.

FIG. 55.

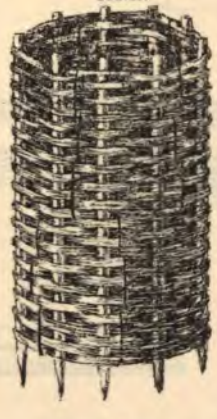


FIG. 56.

FIG. 58.

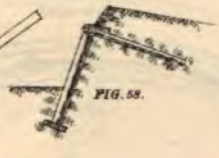
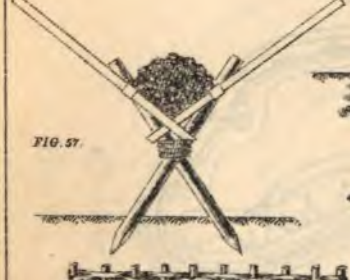


FIG. 57.



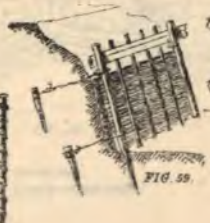


FIG. 59.

FIG. 60.

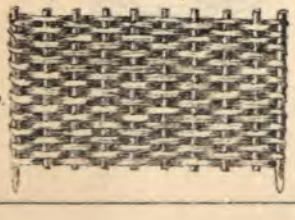


FIG. 61.

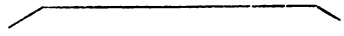


FIG 62

FIG 63.

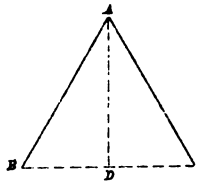
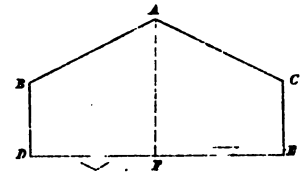


FIG 64.

FIG. 65.



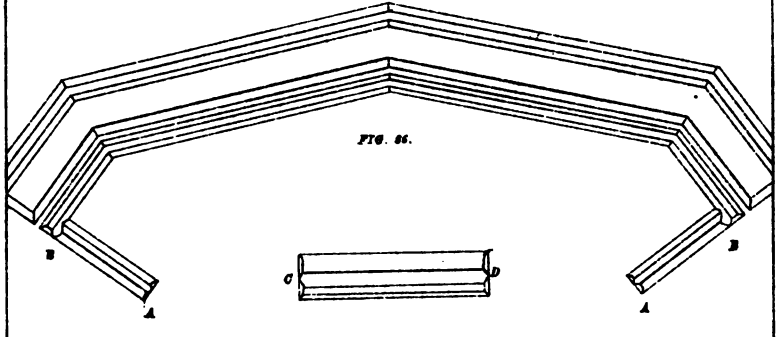


FIG. 66.

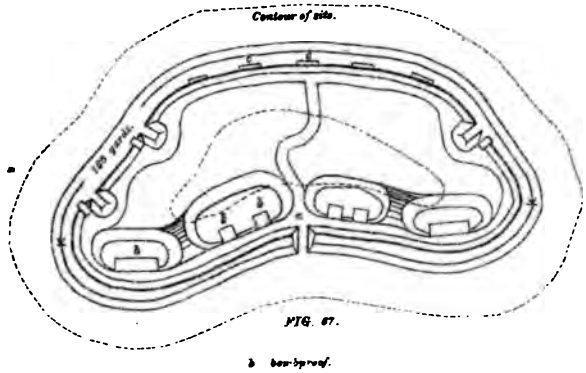


FIG. 67.

b bomb-proof.
c bomb or splinter-proof.

FIG 68

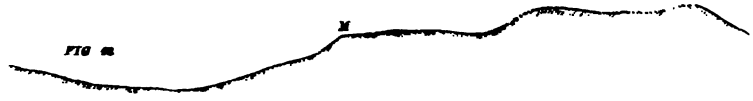


FIG. 69.

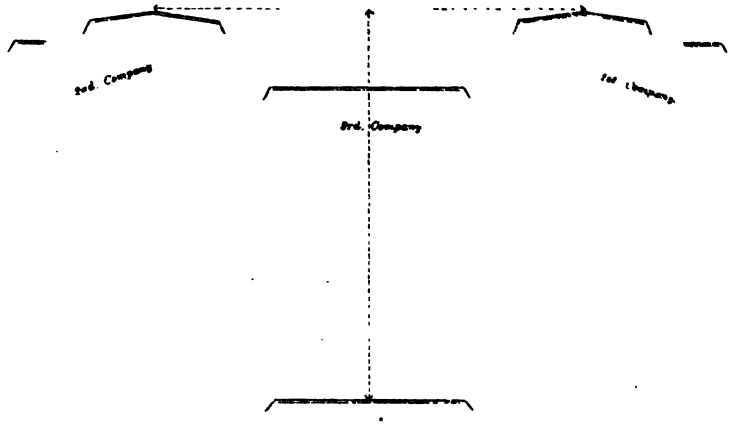


FIG. 70.

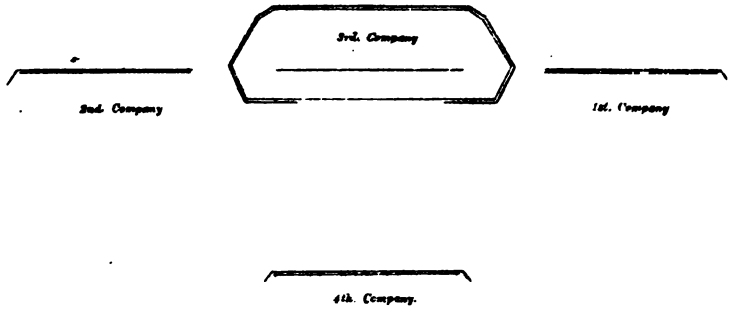


PLATE IX A

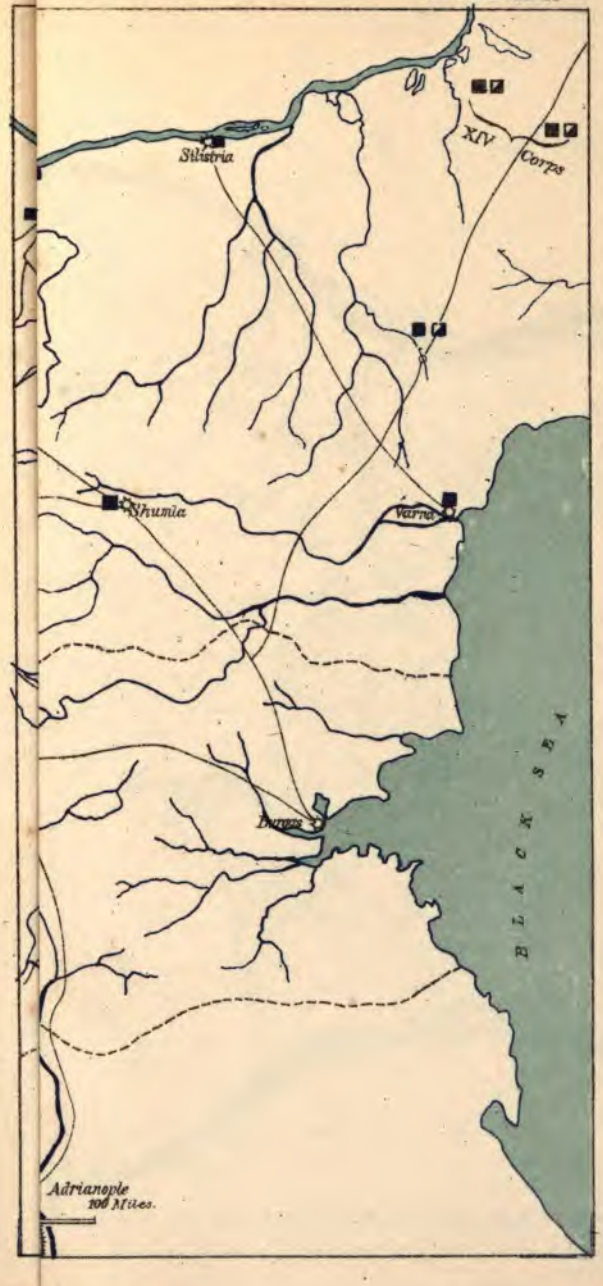

Silistria
XIV Corps
Shumla
Varna
Burgas
BLACK SEA
Adrianople
100 Miles.

PLATE X.

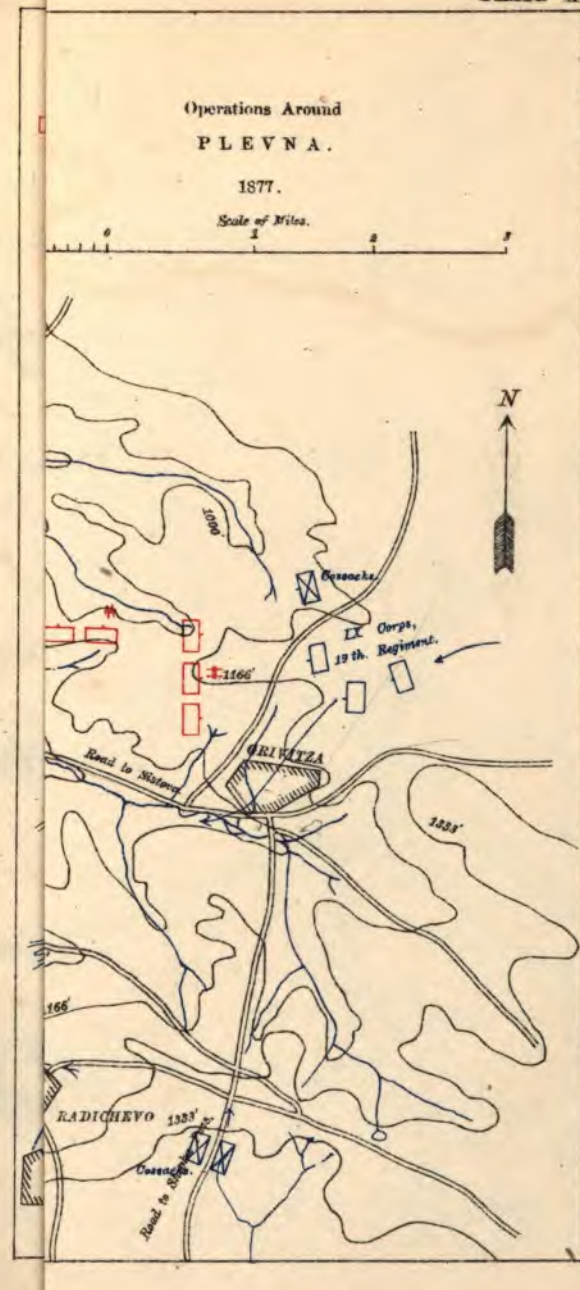

Operations Around
PLEVNA.
1877.
Scale of Miles.
0
1
2
3
N
1000'
Cossacks.
IX Corps,
19 th. Regiment.
1166'
GRIVITZA
Road to Sistova
1333'
166'
RADICHEVO
1333'
Cossacks.
Road to Sistova

PLATE XI

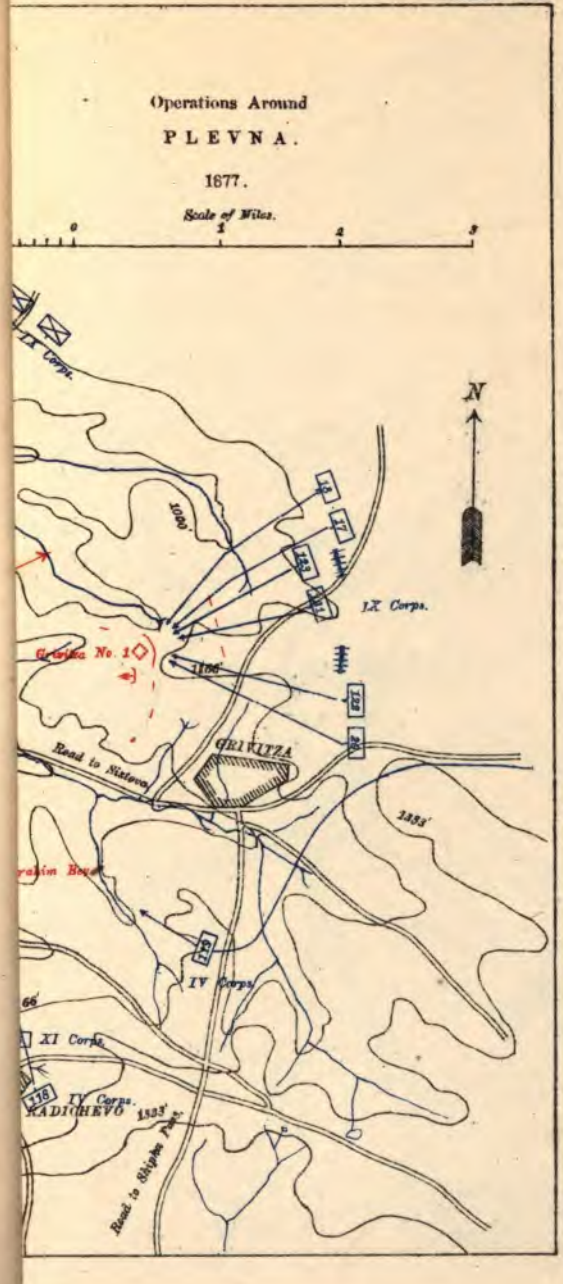

Operations Around
PLEVNA.
1877.
Scale of Miles.
0
1
2
3
N
IX Corps.
1000'
18
17
123
IX Corps.
Grivitza No. 1
1166'
122
GRIVITZA
Road to Sistova
1333'
IV Corps.
66'
XI Corps.
118
IV Corps.
RADICHEVO
1333'
Road to Shipka Pass.

PLATE XII.

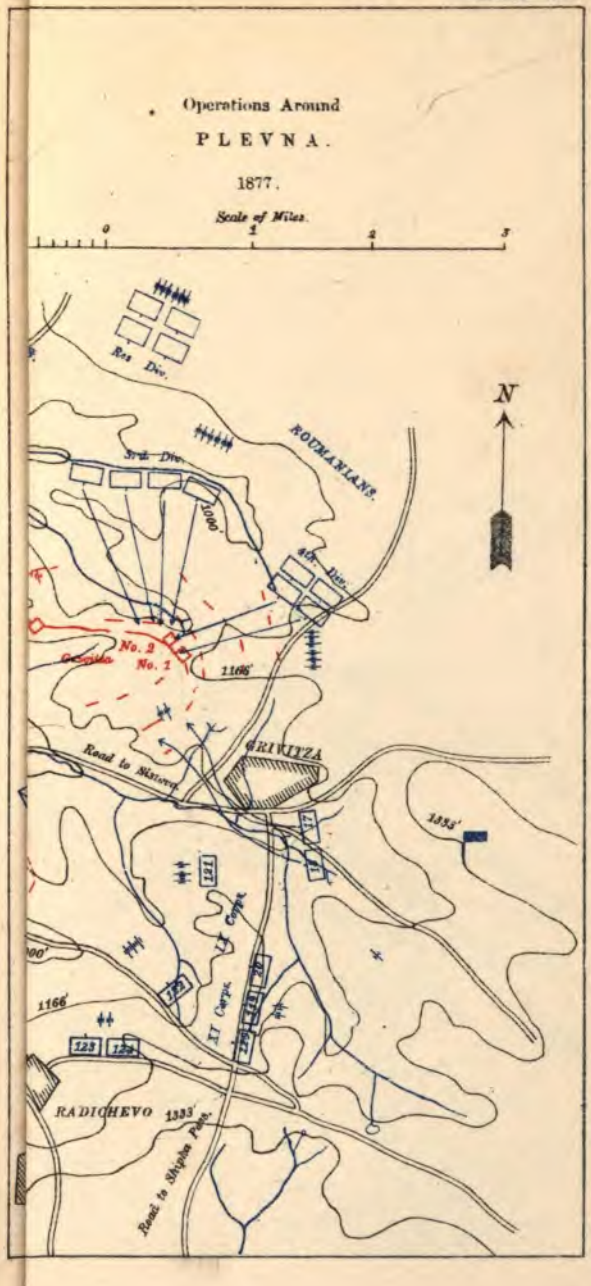

Operations Around
PLEVNA.
1877.
Scale of Miles.
0
1
2
3
N
Res Div.
ROUMANIANS.
3rd Div.
4th Div.
1000'
No. 2
No. 1
1166'
GRIVITZA
Road to Sistova
1333'
121
IX Corps
XI Corps
1166'
123
RADICHEVO
1333'
Road to Shipka Pass.

PLATE XIII.

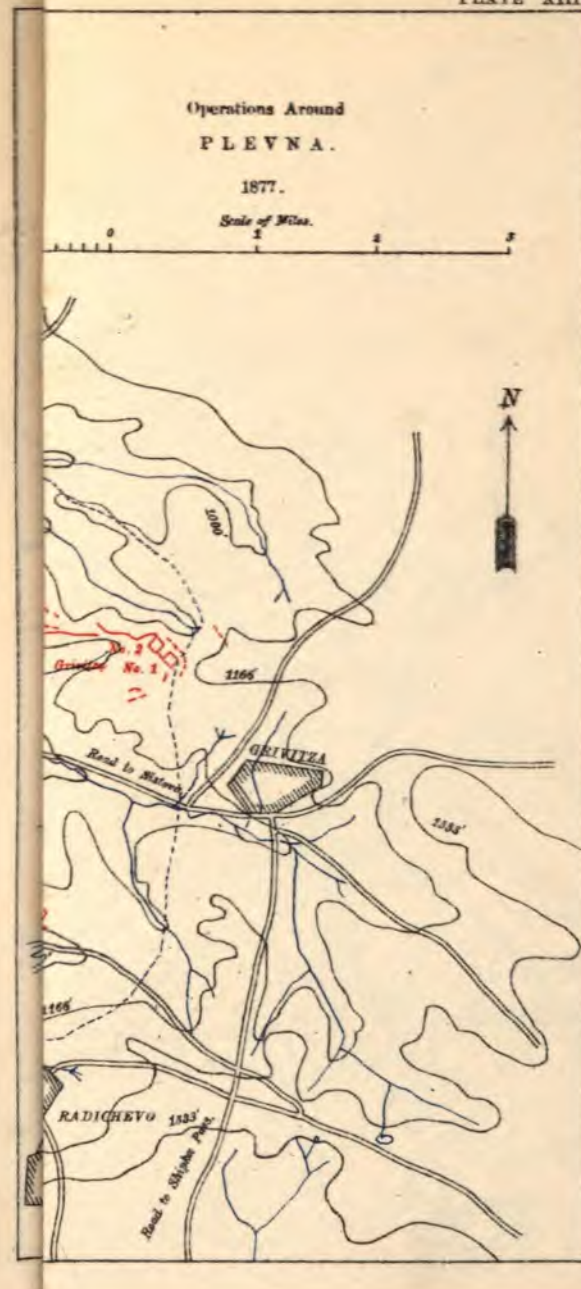

Operations Around
PLEVNA.
1877.
Scale of Miles.
0
1
2
3
N
1000'
No. 2
Grivitza No. 1
1166'
GRIVITZA
Road to Sistova
1333'
1166'
RADICHEVO
1333'
Road to Shipka Pass

PLATE XIV.

Defenses of
WASHINGTON.
1865.
N.
Scale of Miles.
0
1
2
3.
Ft. Carroll.
Ft. Foote.
ALEXANDRIA.
Hunting Creek.
Accotink Turnpike.
Ft. Lyon.
Ft.
Rockville Ro
Ward.
Little River Turnpike.
O. & A. R. R.

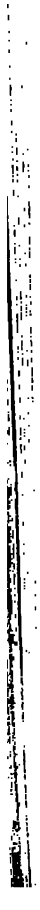


PLATE XV.

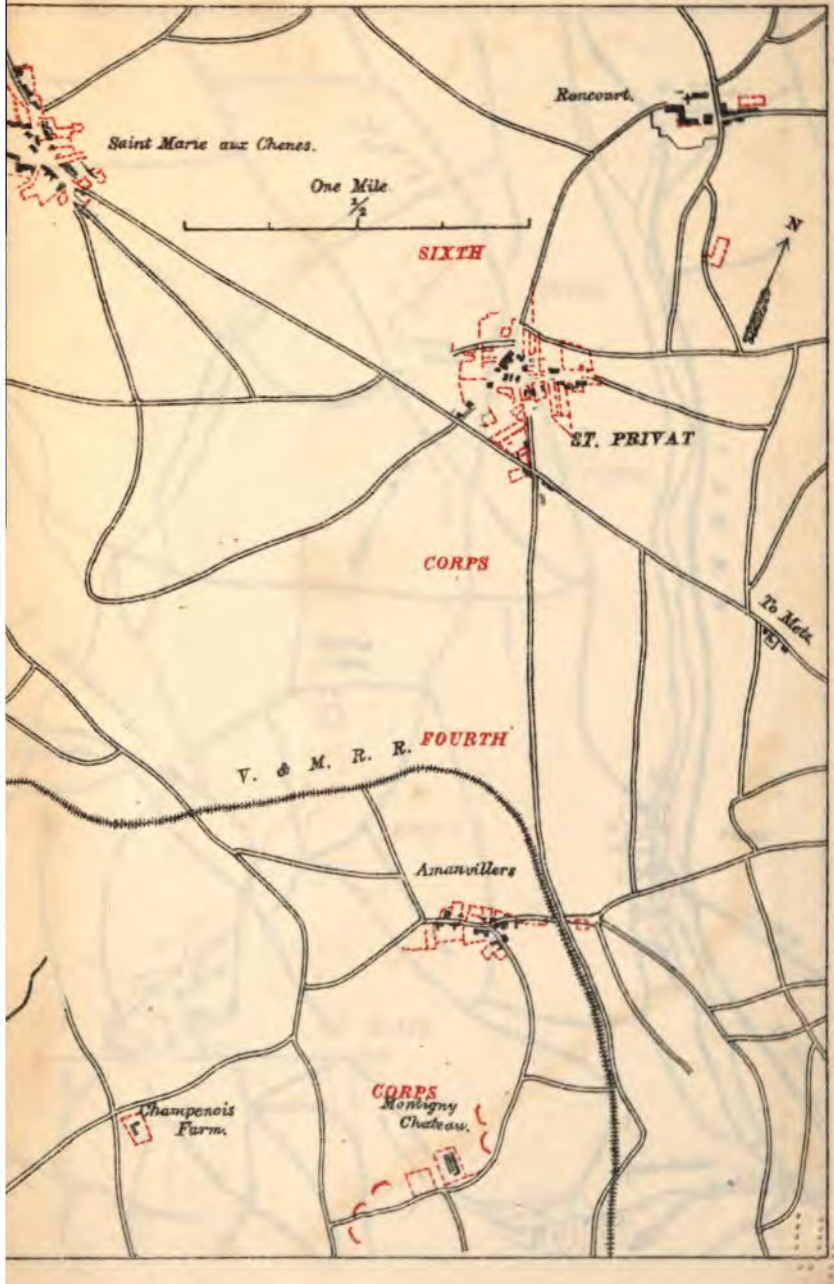

Rancourt.
Saint Marie aux Chenes.
One Mile
SIXTH
N
ST. PRIVAT
CORPS
To Metz
V. & M. R. R.
FOURTH
Amanvillers
CORPS
Champenois Farm.
Montigny Chateau.

PLATE XVI.

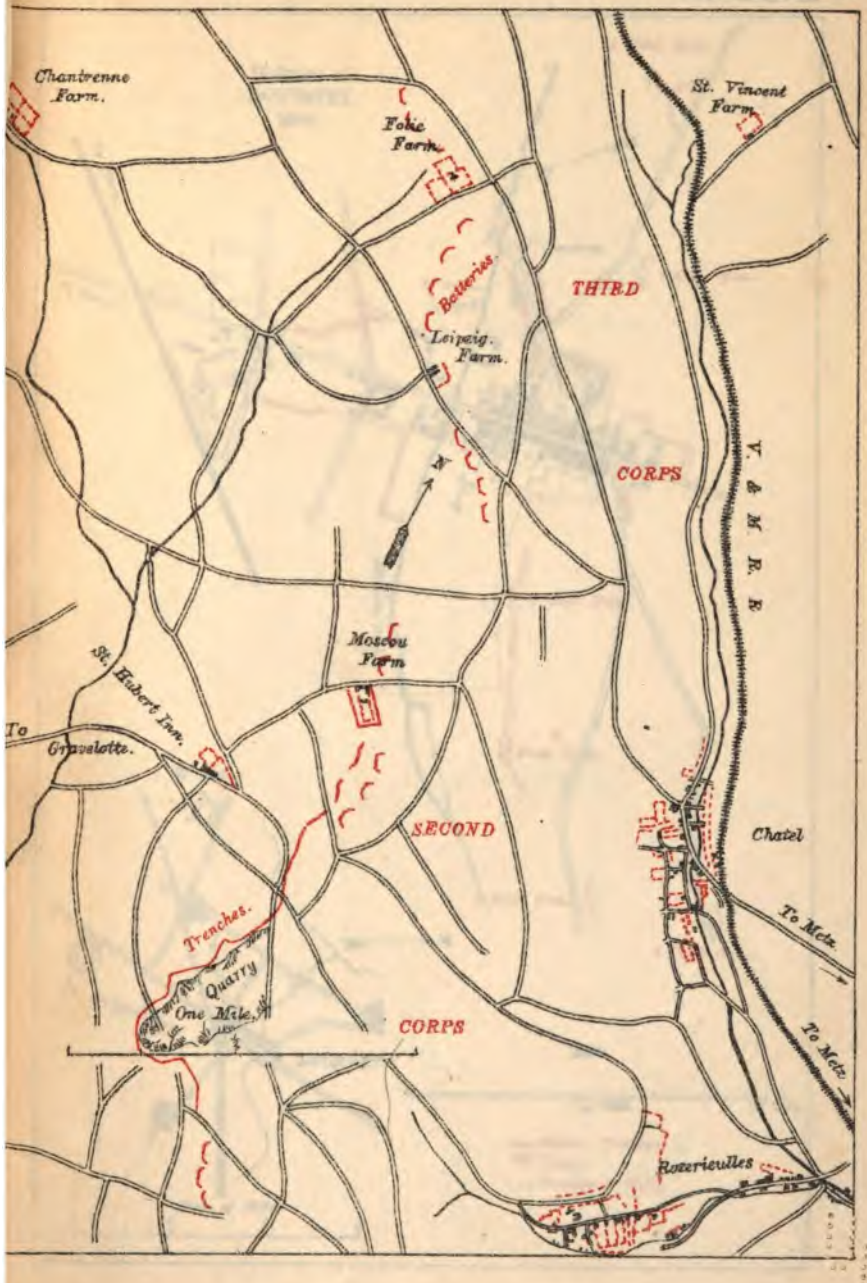

Chantrenne Farm.
Folie Farm.
St. Vincent Farm.
Batteries.
THIRD
Leipzig. Farm.
CORPS
V. & M. R. R.
Moscou Farm
St. Hubert Inn.
To Gravelotte.
SECOND
Chatel
To Metz.
Trenches.
Quarry
One Mile.
CORPS
To Metz.
Rozerieulles

PLATE XVII.

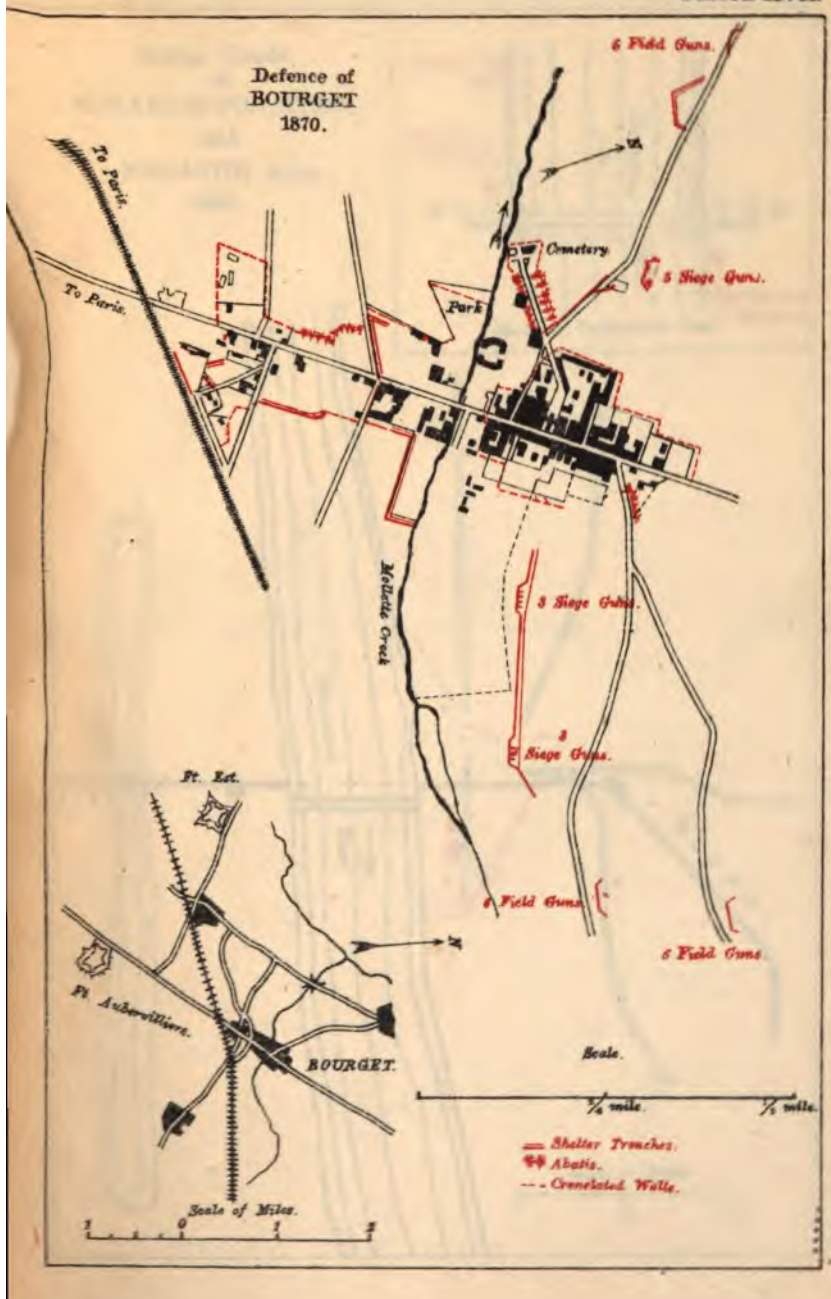
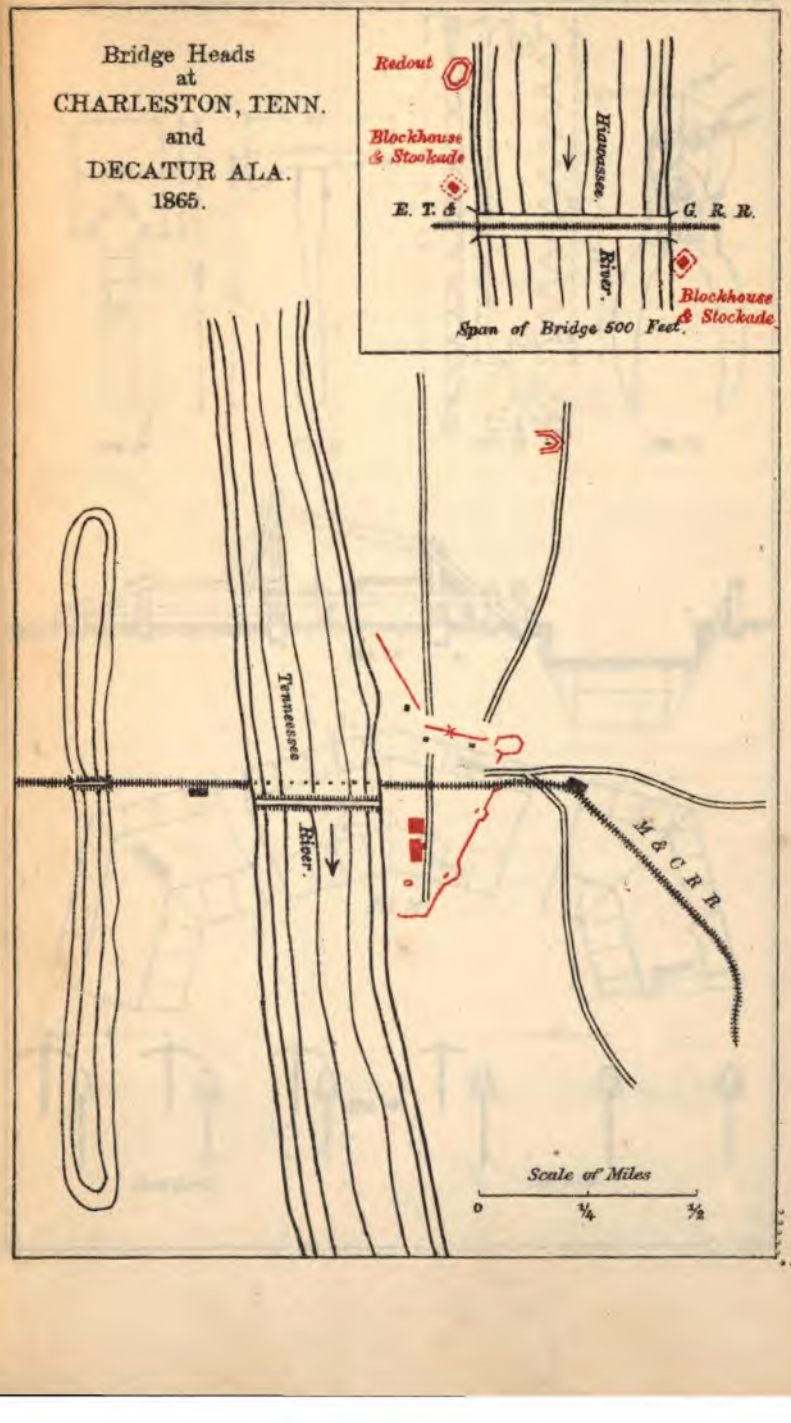

Defence of
BOURGET
1870.
To Paris.
To Paris.
6 Field Guns.
Cemetery.
5 Siege Guns.
Park
Molette Creek
3 Siege Guns.
3
Siege Guns.
Ft. Est.
6 Field Guns.
5 Field Guns.
Ft. Aubervilliers.
BOURGET.
Scale.
1/4 mile.
1/2 mile.
Shelter Trenches.
Abatis.
Crenelated Walls.
Scale of Miles.
1 0 1 2

PLATE XVIII.


Bridge Heads
at
CHARLESTON, TENN.
and
DECATUR ALA.
1865.
Redout
Blockhouse & Stockade
E. T. & G. R. R.
Hiawassee River.
Blockhouse & Stockade
Span of Bridge 500 Feet.
Tennessee River.
M & C R R
Scale of Miles
0
¼
½

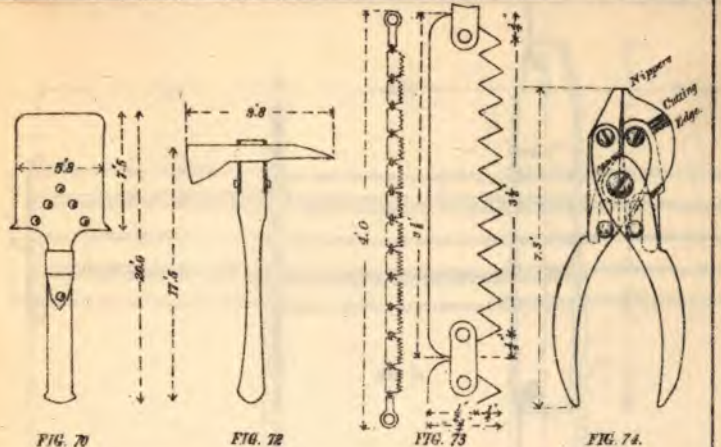


FIG. 70 FIG. 72 FIG. 73 FIG. 74.

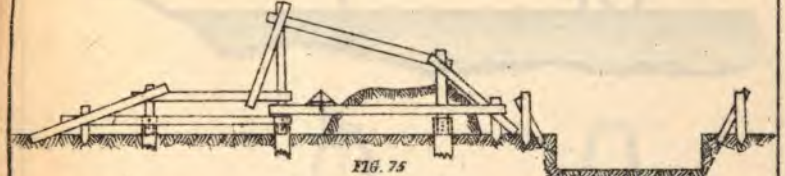


FIG. 75

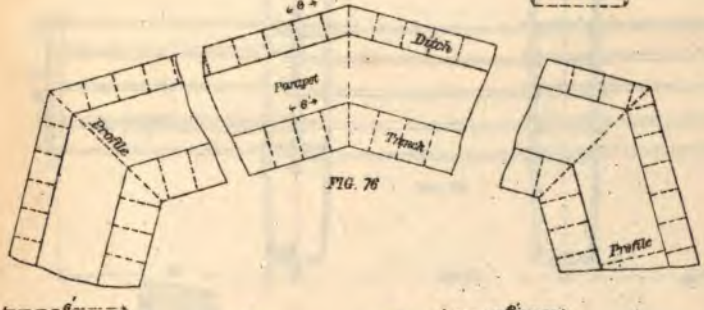


FIG. 76

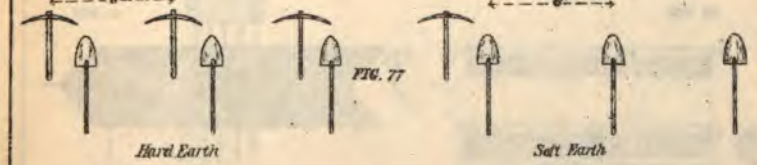
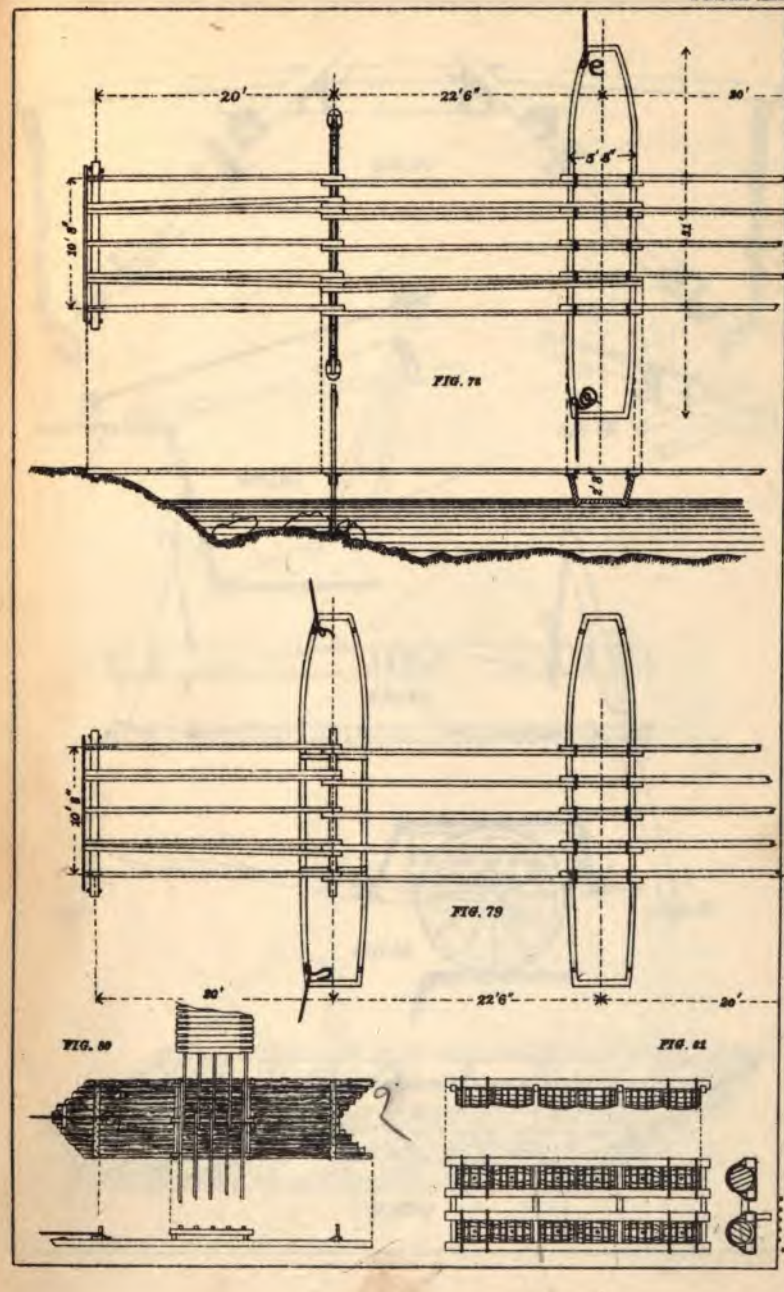


FIG. 77

PLATE XX



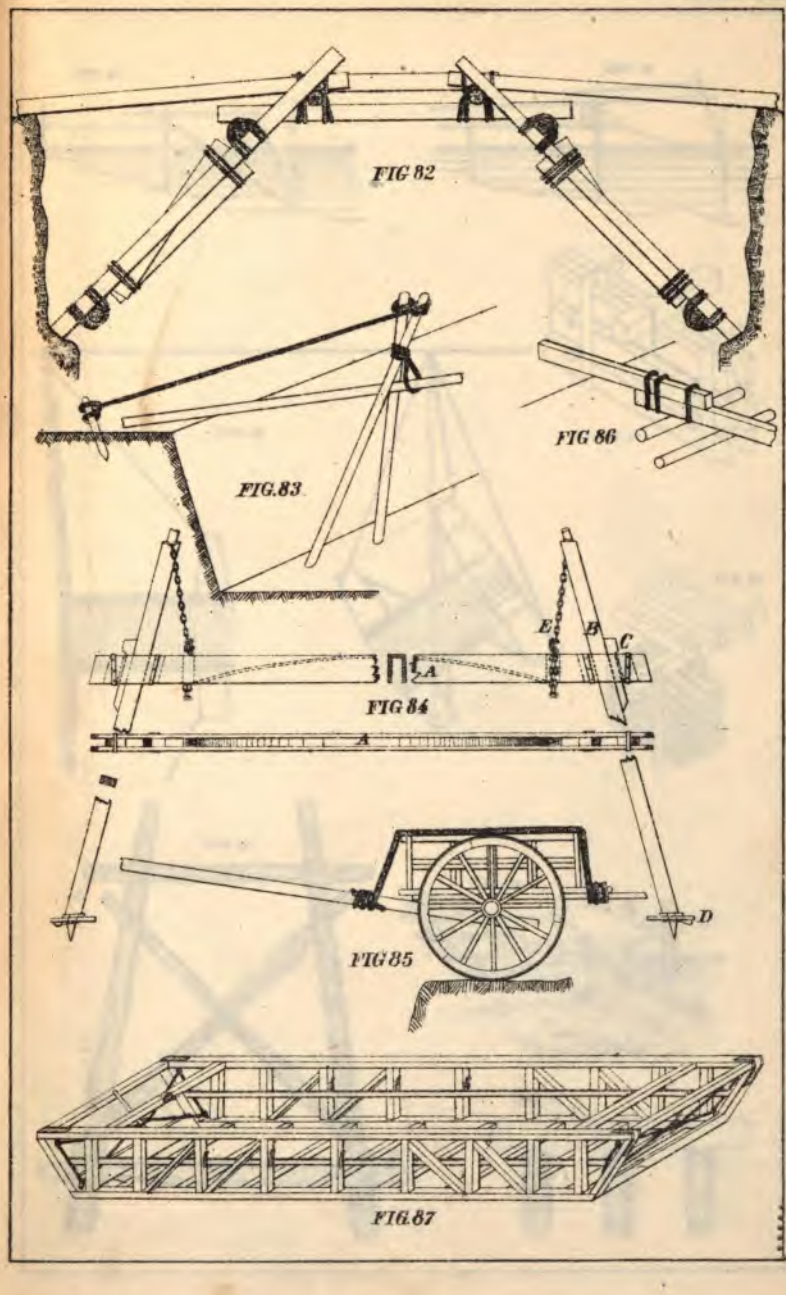
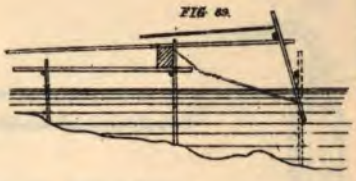


FIG 82
FIG 86
FIG.83
E
B
C
A
FIG 84
A
D
FIG 85
FIG.87

FIG. 88

FIG. 89.



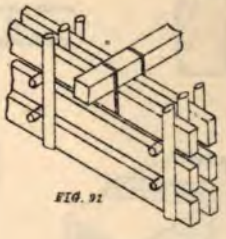


FIG. 91

FIG. 90

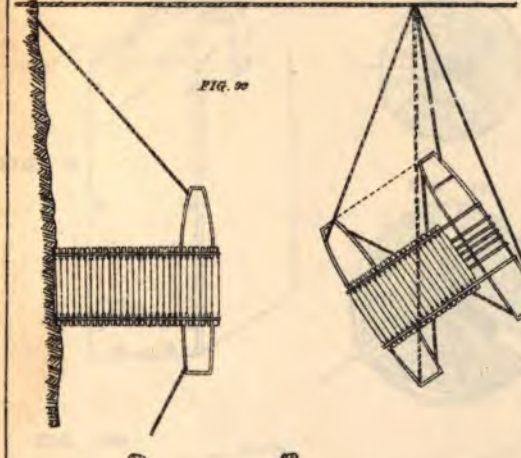


FIG. 92

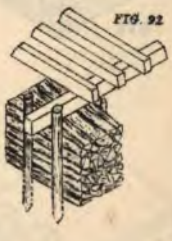


FIG. 93

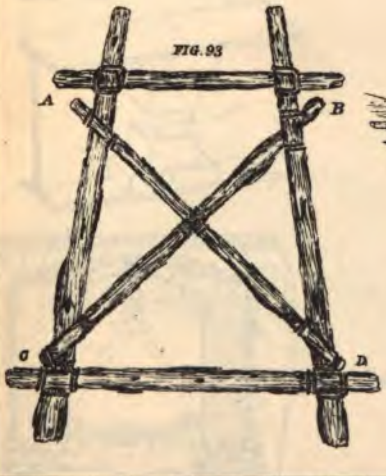


FIG. 94

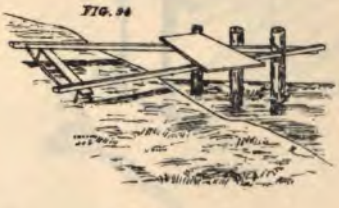


FIG. 95

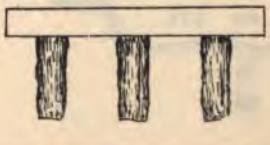


FIG. 96

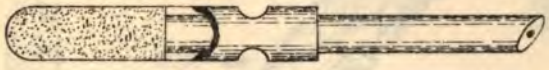


FIG. 97

FIG. 98

A

FIG. 99

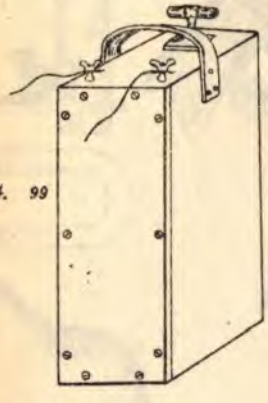


FIG. 100

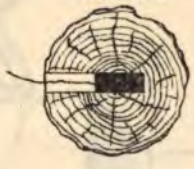


FIG. 101

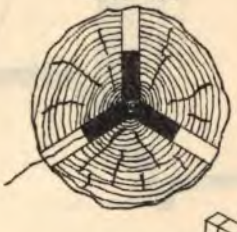


FIG. 102

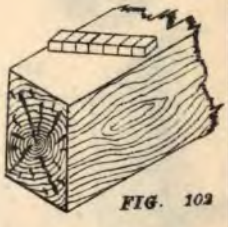


FIG. 103

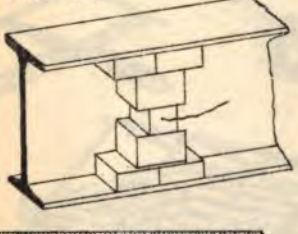


FIG. 104

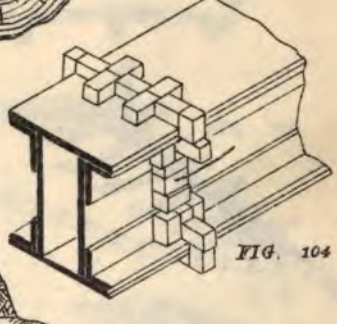


FIG. 105

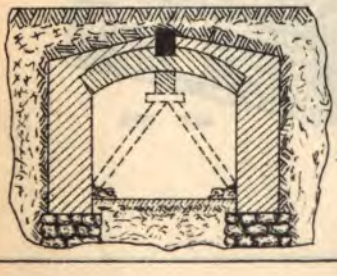
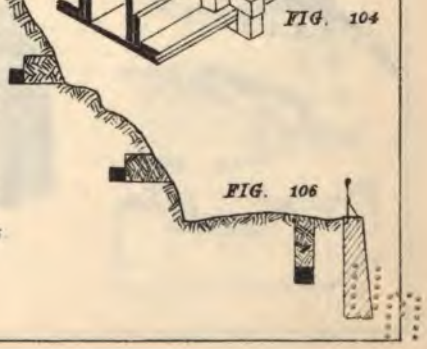


FIG. 106



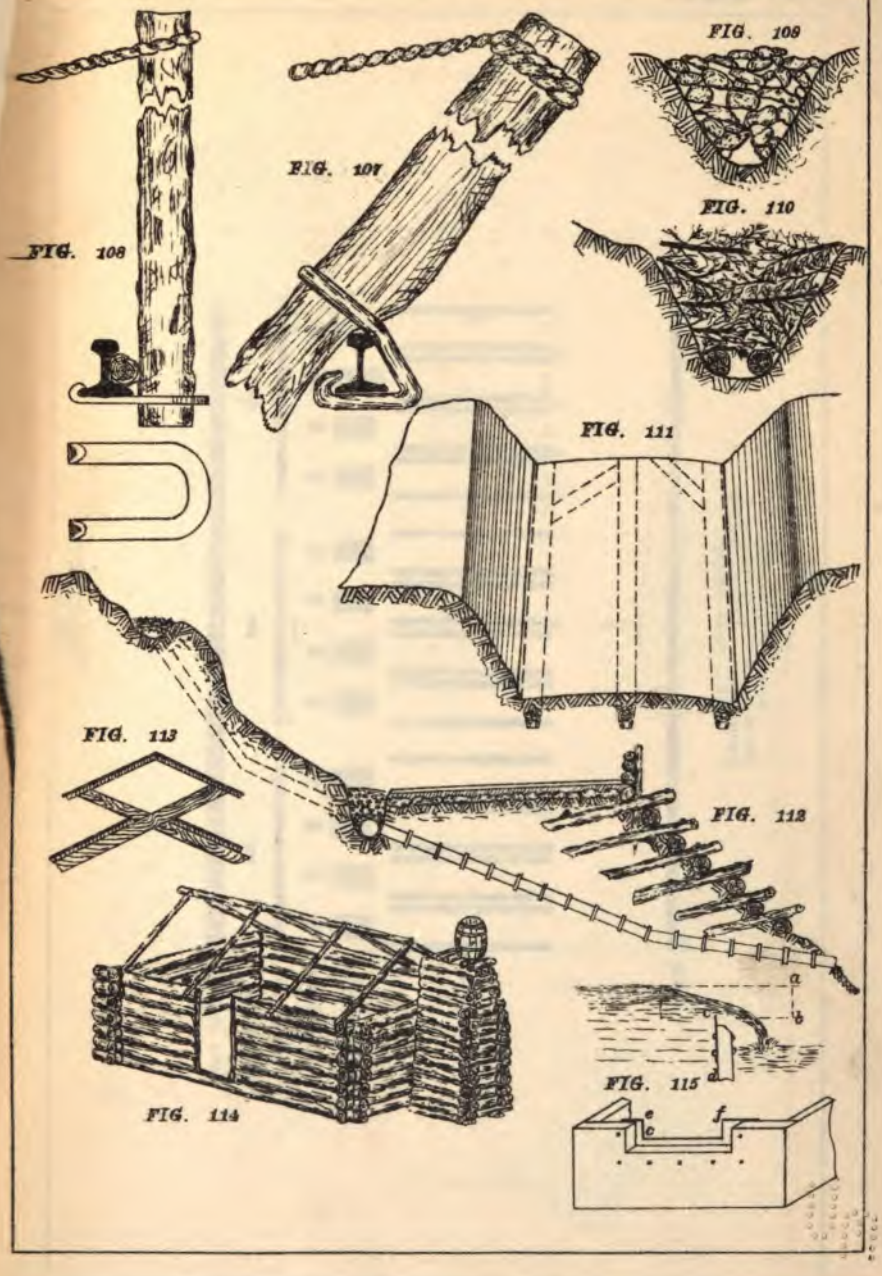
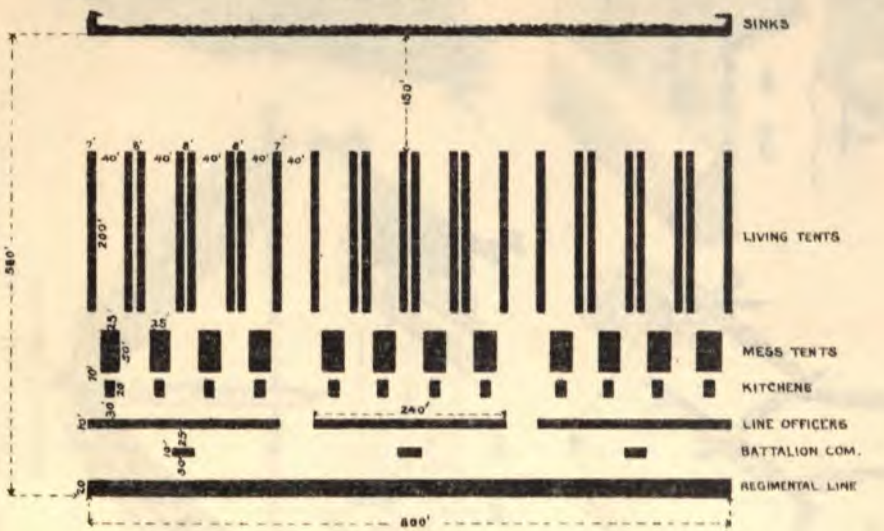


FIG. 108
FIG. 107
FIG. 109
FIG. 110
FIG. 111
FIG. 113
FIG. 112
FIG. 114
a
b
FIG. 115
e
f

PLATE XXV.

PLAN
OF
REGIMENTAL CAMP.
IN ACCORDANCE WITH ORDERS OF THE
MAJOR GENERAL COMMANDING,
SECOND ARMY CORPS.



OFFICE CHIEF ENGINEER
2ND ARMY CORPS
AUG 24, 1918.

FIG. 116

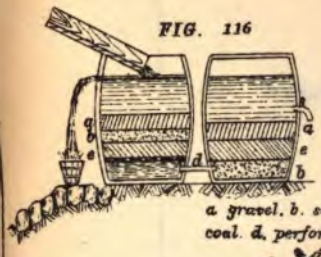


FIG 117

a. gravel. b. sand. c. charcoal. d. perforated plate.

FIG. 118

FIG. 119

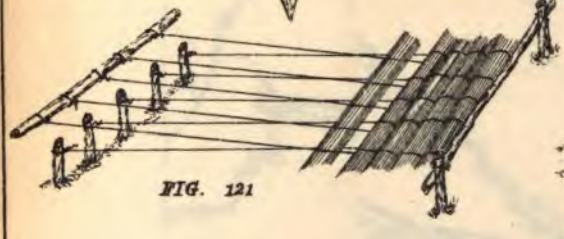
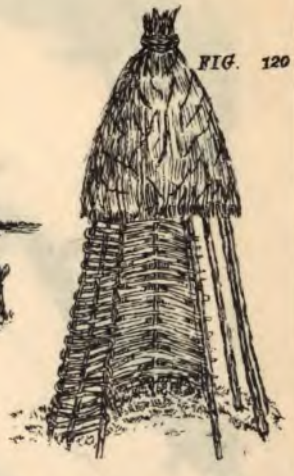


FIG. 121

FIG. 120



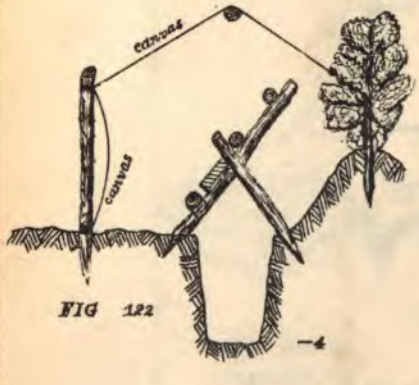


FIG 122

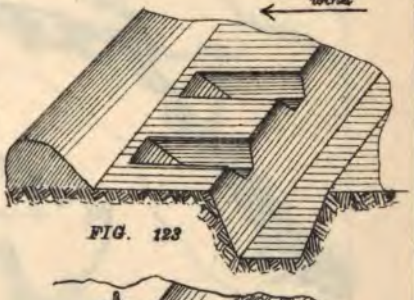


FIG. 123

FIG. 124

PLATE XXVII

VIRGIN
N
POTOMAC RIVER
Orange
Charlottesvil
Tenn. R.R.
Va. and
JAME
Mattapony
River
White House
West Point
YORK RIVER
Appomattox C.H.
Charles City C.H.
JAMES RIVER
— Union Intrench
— Confederate Int

SHORT-TITLE CATALOGUE

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